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TROPICAL AGRICULTURE

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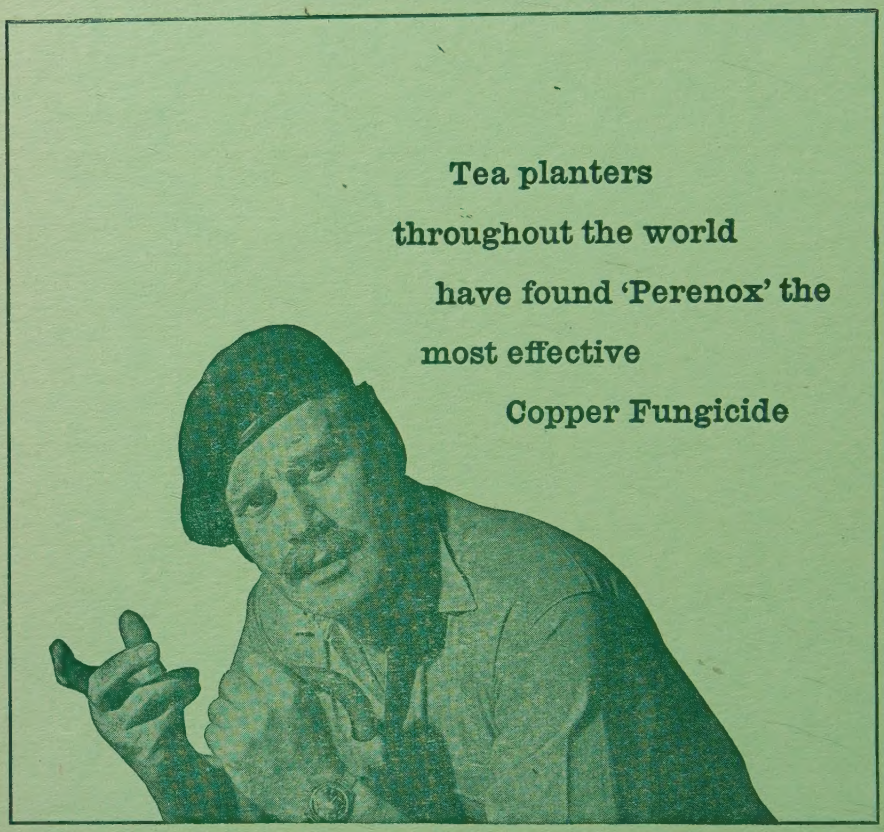

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Shifting Cultivation

An appeal by FAO to governments, research centres, associations and private persons who are in a position to help

EDITORIAL NOTE

(It is with great pleasure that *Tropical Agriculture* has received permission from the Food and Agriculture Organization of the United Nations to reprint the following article on ' Shifting Cultivation ', which has been prepared by FAO staff, from *Unasylva*, Vol. **11**, No. 1, 1957. We hope that in this way the appeal which FAO makes for information and assistance will be given wider publicity among tropical agronomists. FAO has recently appointed Monsieur P. de Schlippe, a well-known agronomist with experience in the Belgian Congo and the Sudan and author of ' Shifting Cultivation in Africa: the Zande System of Agriculture ', as consultant on shifting cultivation. Any assistance which our readers can give in ideas and information will be of the greatest value to M. de Schlippe and his colleagues. The article which follows is self-explanatory, and we commend its appeal to our readers' attention.)

Shifting cultivation, in the humid tropical countries, is the greatest obstacle not only to the immediate increase of agricultural production, but also to the conservation of the production potential for the future, in the form of soils and forests. This has been borne out in several FAO conferences and in correspondence with many Member Governments.

Over the past few years, FAO has undertaken a limited number of case studies, stressing the forestry aspects of the problem. The intention is to follow up the publication of these case studies with analyses of the effects of shifting cultivation on soils and forests, as well as with proposals for improving the situation. This entails the study of all facets of the problem. FAO has, therefore, the intention of mobilizing the contributions of as many scientists as possible to help solve this problem in all interested countries.

In order to reach a better understanding of the problem, an attempt is made in this article to define shifting cultivation, to evaluate its actual dimensions, to postulate its probable causes, to draw the approximate geographical and cultural boundaries of its area and, finally, to project the main lines of action to overcome its disadvantages.

This first step should stimulate interest among those experts who, in one way or another, are in touch with this vast problem. It is with the help of their response to the request made by FAO that real and more systematic coordination will become possible. This will be achieved through questionnaires, publications, meetings, seminars and conferences until ideas have crystallized sufficiently for concrete lines of action to be recommended to the various governments interested in the problem.

THE BLIND ALLEY OF CULTURAL DEVELOPMENT

Shifting cultivation is the custom of cultivating clearings scattered in the reservoir of natural vegetation (forest or grass-woodland) and of abandoning them as soon as the soil is exhausted; and this includes the custom of shifting homesteads in order to follow the cultivator's search for new fertile land.

These nomadic habits have the following grave consequences:

(1) The fallow, which restores soil fertility, is identical with natural vegetation which remains outside human control, outside the possibility of improvement.

(2) Therefore, soil and forest resources are being wasted by bush fires, erosion and other factors.

(3) Man is never induced to intensify his agriculture, nor to proceed with long-term improvements of his land.

(4) Having to move away periodically, he does not accumulate any permanent material wealth.

(5) Beyond a certain critical limit, the density of population cannot increase as, at the approach to this limit, all the soil becomes degraded and famines redisperse the population.

(6) No concentrations or agglomerations of the population can, therefore, take place and no urbanization is possible, which means that the cultivators have to remain economically at a subsistance level, without professional differentiation, without exchange or specialization, i.e. without any possibility of progress.

(7) Where cash crops have been introduced in an attempt to raise the standard of living of the cultivators, without altering the methods of cultivation, experience has shown that the destructive effects of shifting cultivation have become even greater.

COORDINATES—TIME AND SPACE

Shifting cultivation is not only a backward type of agricultural practice. It is also a backward stage of culture in general. In all respects it corresponds to the Neolithic period through which humanity passed between the years 13,000 and 3,000 B.C., considering that the substitution of iron tools for polished stone has made no substantial difference in the way of life.

It is not easy to establish the geographical boundaries of the total area under shifting cultivation because of the transitory types of culture which surround it, but very roughly one could estimate it at 14 million square miles (36 million km^2) inhabited by some 200 million people. The average density of only 14 men per square mile (6 per km^2) is so low that a world in expansion cannot tolerate this relative vacuum. This does not mean that the vacuum should be filled in by migrations, but every country must be capable of contributing its share of agricultural produce for the benefit of all.

Moreover, the industrialization of underdeveloped countries, if proceeding ahead of the stabilization and improvement of rural life, increases 'social distances' between lower and upper classes of society, and this tends to throw it back to obsolete authoritarian forms of social structure.

ECOLOGICAL CAUSES

The area of shifting cultivation corresponds to the rainy tropics, with the exception of all those parts of it where a rich and stable soil permits continuous cultivation, as for example on recent alluvia, on volcanic soils and in high altitudes. It seems to be established that the factor which keeps people at the level of shifting cultivation is in the first place the rapidity with which tropical soils lose their fertility (i.e. their lack of retaining capacity of plant nutrients) and undergo undesirable changes in physical conditions. These difficulties can be split into several factors—low adsorption capacity for exchangeable bases of the clay fractions of the soils, the tendency of these clays to immobilize phosphates, the heavy percolation rate of tropical rains through generally very porous soils and the resulting leaching of plant nutrients, the rapid destruction of organic matter by bacterial action under conditions of high temperatures, and so on.

Where man has to deal with a rapid destruction of soil fertility under conditions of denudation for the purpose of cultivating annual crops, and where he possesses no other means of restoring soil fertility than natural green fallow, he lives in too narrow a dependency on the natural order, without being able to take it under his social and technical control.

TYPES OF SHIFTING CULTIVATION AND CULTURAL BOUNDARIES

The most primitive type of shifting cultivation can be found presumably in equatorial forest areas, where the cultivation of clearings is, economically speaking, no more than a small additional resource to the still more primitive stage of hunting and gathering. On the fringes of the humid tropical belt, in the savanna, more elaborate systems of agriculture are the custom.

Where the homesteads are small, being restricted to family groups, the periodicity of moving is rapid. Where on the other hand village units are big, their nomadic character may be less obvious. In such cases, soil destruction does not immediately lead to migration but to fields being farther and farther removed from the villages, until the stage is reached when a community is faced with economic catastrophe and eventually has to move and settle elsewhere. Areas of such occurrence should also be considered as forming part of the shifting cultivation zone.

On the perimeter of the humid tropics, where dry seasons are long, agriculture is in most cases practised along with cattle breeding. Conventionally one could consider that pastoral nomadism starts where the main reason for moving the homestead is a search for seasonal pastures, whereas the area of shifting cultivation extends to where migrations are due to an agricultural incentive.

In the neighbourhood of areas where soils are enriched by river deposits, there are generally accumulations of people who follow a sedentary way of life. If such areas are sufficiently big to be economically independent, they are obviously outside shifting cultivation. Where, however, a certain amount of rice is grown in marshes by people who otherwise practise shifting dry farming, they, also, could be included in the area. The same applies to pockets of completely sedentary rice-growing communities wherever these are scattered amongst shifting cultivators.

As the altitude increases the soils gradually lose their defect of a transient fertility, and it is not exceptional to see sedentary populations practising continuous cultivation on tropical plateaux, although culturally they are almost at the same level as shifting cultivators. In a study of shifting cultivation these areas are of interest for the purpose of establishing comparisons.

Finally, wherever countries which ecologically belong to the area of shifting cultivation have long been in contact with old civilizations, several transitional cultural levels might have developed which are eminently important in the study of means of overcoming shifting cultivation.

MEANS OF ACTION

At a first glance, three points of attack seem feasible. The first would deal with the main ecological limiting factor, namely the rapid loss of soil fertility. The second would consist of the adaptation of all inventions of modern life which could help the shifting cultivators to emerge from their blind alley, and this even where the first line of action should yield but meagre results. The third line of attack would involve methods of guiding the major social change involved in the transition from a nomadic way of life to a sedentary one and to civilization. This major social change will be necessary in any case, whether grafted on improved soil conditions or on the introduction of various agricultural and technological improvements, or both.

SOIL SCIENCE RESEARCH

FAO would be particularly grateful for all suggestions for research in soil science directed towards the solution of the problem as stated above. In the first place, the overall productivity of tropical soils could be increased by appropriate methods of soil management and especially by intensifying and improving the regenerative effect of the fallows. This is achieved first by protecting the fallow, but could be further enhanced by replacing the natural bush and grass fallows by planted scrub and grass fallows and finally by fertilizing these. Other actions such as finding means of making the effect of fertilizers last longer, and even altering the structure of the soil, may be suggested. At this stage, it is not wise to limit the choice of suggestions and the lines of approach as much may still have escaped attention. Accounts of all the experience so far acquired in experimental work, especially along the lines of the corridor system as practised in the Belgian Congo, would be very gladly received.

There is a particular need for a critical evaluation of the benefits that accrue to the tropical soils from natural fallows. Such an evaluation may open the door to revolutionary improvements in the management of these soils and thus provide the foundation for a radical improvement in the lives of people in the areas of shifting cultivation.

AGRICULTURAL AND TECHNICAL ADAPTATIONS

In many countries, attempts have been made to fix shifting population by resettlement. This has yielded positive results only where the establishment of appropriate crop rotations has been introduced in local practice.

The introduction of a crop rotation is dependent on alterations in land tenure systems and with them the social structures. As soon as this fundamental measure of introducing crop rotation was taken—in other words, as soon as a technical and legal basis was created for the exercise of a certain control over the fallow—a number of other measures became possible. In the first place, as already mentioned, an intensification of the fallow by protecting, planting and manuring it, in turn opens up possibilities for mechanizing cultivation. The establishment of permanent roads and paths has made it possible to shorten distances by mechanizing transport. This also makes it possible to introduce time-saving devices such as collectively-owned pumps and mills. Some of the production of food in a sedentary way of life has been taken over by permanent tree-plantation, which conserves the soil better than annuals, and some by the creation and stocking of fishponds. Finally, all this leads to the possibility of increasing productivity by exchange and specialization, including an occupational differentiation between craftsmanship, cattle breeding, agriculture and forestry.

It would be desirable to make an inventory of any application of these and other interdependent measures, and to relate their success to demographic conditions (critical minima and maxima of population densities), to nutritional and economic conditions (measurable not by money incomes but preferably in units of effort at the production end, in calories and units of protein at the consumption end), and to social and cultural conditions, i.e. to the people's contentment, to the degree of their participation in progress and their acceptance of it.

THE GUIDED SOCIAL CHANGE

Until now, the cultural development of humanity has followed a process of trial and error, which is not only slow but also dangerous as it leads through crises and catastrophes. Even at present the 'acculturation' of backward people, despite the experience of history at our disposal, is carried out by methods not planned in advance. In order to raise 200 million people in one or two generations to a point of cultural evolution which has normally taken some 5000 years to attain, and in order to do it smoothly, crushing neither the forces of cohesion of the society nor its adhesion to the natural environment, one may need to devise new, more appropriate methods of education and of administration.

Considering the great cultural disparity between the level of the people concerned and that of the scientists who should be entrusted with initiating the social change, it might be essential to open up and ensure new channels for the participation of the people in the direction of their own movement.

It seems also necessary to revise survey methods for the study of ecological conditions (soil, phytosociology, ecoclimate) and cultural conditions (social structures, land tenure and customary systems of agriculture) which together form the starting point to the social change. Until now, surveys give but little information on the logical connection between environment and culture.

Moreover, sufficiently definite criteria are not yet available for judging the progress of the social change, in order to adjust the reforms if need be.

It should be of the greatest importance to gather all documentation possible on recently acquired experience in appropriate methods of regional planning.

FAO APPEAL

It is only by coordinating the work of various specialists that positive contributions will become possible. The level at which this coordination is probably the most important, is that of the small problem areas in which contact between the tutors initiating progress and the populations which will have to profit from it is actually established.

Nevertheless, it is also important to centralize all the documentation available on the problem at an international level and to coordinate the theoretical work on means of overcoming shifting cultivation. That is what FAO proposes to do.

It appeals to all those who have acquired experience in the various branches connected with the problem to help by sending in suggestions and criticism and by indicating bibliographical sources at their disposal. The next step will be to issue systematic questionnaires, each adapted to the disciplines involved.

From universities, FAO would like to receive suggestions concerning the best methods of training teams of specialists and inter-disciplinary coordinators who will be required for the campaign to overcome shifting cultivation.

NOTE: *All those wishing to keep in touch with FAO on the subject of shifting cultivation are asked to communicate with the Director, Agriculture Division, or the Director, Forestry Division, at FAO Headquarters, Viale delle Terme di Caracalla, Rome.*

History and Functions of Botanic Gardens with Special Reference to Singapore

J. W. Purseglove
Director of the Botanic Gardens, Singapore

Many people think of botanic gardens as public parks in which to stroll amid pleasant surroundings and admire beautiful and rare flowers. Others consider them a convenient exercising ground for the baby or the dog, a good place for picnics, and, in Singapore, somewhere to feed the monkeys.

DEFINITION OF BOTANIC GARDENS

Any public park can provide these amenities. Why then go to the expense of maintaining botanic gardens with their staff of botanists, horticulturists and other specialists ? The answer is that botanic gardens, to merit the name, are gardens maintained for the scientific study of the plants. As soon as this vital function is neglected botanic gardens change to public parks. This has been the fate of many botanic gardens throughout the tropics, while others have been totally neglected or have disappeared. It is true that they sometimes sell or give away planting material of fruit trees and ornamental plants, but this function can be undertaken by agricultural stations or commercial nurseries.

BOTANIC OR BOTANICAL

Some gardens such as those at Kew and Singapore are proud of the name Botanic Gardens, all too frequently called Botanical Gardens by the public, while others, especially in America, style themselves Botanical Gardens. Why is this ? Botanic is the older form of adjective, but is now mostly superseded by botanical, except in the names of institutions founded long ago. It is advisable to ascertain which adjective is used by any particular gardens in order not to give offence. Some, such as the Royal Botanic Garden, Edinburgh, do not use the plural of the noun.

THE FIRST BOTANIC GARDENS

The oldest botanic gardens in existence today are those of Pisa in Italy founded in 1543, closely followed by those of Padua. They were founded by the Universities and were herb gardens in which the future physician was taught the medicinal use of herbs and how to recognize them. The Jardin des Plantes was founded by Louis XIII in Paris for this same purpose in 1626, as were the Oxford Botanic Gardens by the University in 1621, and the Chelsea Physic Garden in 1673 by the Apothecaries Society.

SYSTEMATIC STUDY OF PLANTS

In the eighteenth century Linnaeus laid out a garden showing his new system of classification and the plants were labelled in accordance with his binomial nomenclature. Other gardens followed suit and were designed to illustrate a purely scientific concept. Living plants, as well as herbarium

specimens, were brought from all over the world for study in temperate countries. Botanists were often attached to voyages of exploration to collect and bring back this material. Many of the famous gardens of Europe, including the Kew Royal Botanic Gardens, founded in 1759, carried out these early taxonomic studies. (The first Botanic Gardens in the United States of America were not founded until the nineteenth century.) The herbaria and libraries which are so essential for this work were accumulated and the systematic study of plants, sometimes on a local basis, sometimes on a world basis, is still one of the most essential functions of modern botanic gardens.

FOUNDING AND WORK OF THE EARLY TROPICAL GARDENS

As far as I can ascertain the oldest botanic gardens in the tropics are those of Pamplemousses in Mauritius which were established by the French in 1735. HART's (1919) history of these gardens makes fascinating reading and is typical of many tropical gardens elsewhere. They started as a pleasure garden, although cassava was first introduced as early as 1736. After periods of neglect their principal function was to obtain, grow and distribute seeds of economic plants, particularly of spices, hitherto only cultivated by the Dutch in the Moluccas. Nutmegs were first introduced in 1765, but died. Among the introductions in 1767 were pepper, cinnamon, fruit trees and other plants yielding dyes and varnishes. Expeditions in 1770 and 1772 brought back nutmegs and cloves. The gardens were laid out in a picturesque manner and planted with native, African, Indian, Malayan and Australian plants. They suffered from subsequent periods of neglect, but later played a prominent part in the founding of the Mauritius sugar industry. They were taken over by the newly formed Agricultural Department in 1913.

The first British tropical botanic gardens are those of St Vincent founded in 1764 (CHIPP, 1920). Bligh was commissioned to obtain bread-fruit for these gardens from Tahiti and his expedition ended in the famous mutiny of the *Bounty* in 1787; he was more successful in 1791 and brought back bread-fruit plants to the West Indies. These gardens were abandoned for some 60 years later in their history. Among the other early botanic gardens founded in dependent territories are Jamaica in 1774, Calcutta in 1786, the first of the three Penang Botanic Gardens in *ca.* 1796, Buitenzorg (now re-named Bogor) in 1817; Trinidad in 1819, Peradeniya (Ceylon) in 1821 and the first Singapore Botanic Gardens in 1822. Typical of all these gardens is the founding of the first botanic gardens in the north American continent when Charles III of Spain sent a scientific expedition to Mexico in 1781, when ' one of its objects was to establish a botanic garden in which instruction should be given in botany and in which the native products of the country should be cultivated and preserved ' (RICKETT, 1956).

In addition to the very important function of collecting, growing and distributing indigenous and exotic economic crops of promise, as well as seedlings of timber trees, and giving advice to the early planting communities on methods of cultivation and the control of pests and diseases, many of these botanic gardens laid a sound foundation of botanical research in the tropics in the nineteenth century. Many of the early directors were men

of outstanding ability and industry. First and foremost they were keen botanists and could not help but be interested in the wild plants growing around them, many of which were as yet undescribed. They made arduous collecting trips into little-known country bringing back living plants for trial in their gardens, as well as large numbers of herbarium specimens. These were exchanged with other institutions throughout the world, and as time went on local floras and monographs of particular groups were prepared. The world owes these great pioneers a considerable debt.

By the second decade of the twentieth century most tropical territories had inaugurated independent agricultural and forestry departments, and much of the work on crops and forest products was handed over to them. Many of the botanic gardens were absorbed into the new agricultural departments, often with disastrous results to the research in botany which they had hitherto undertaken. The role of botanic gardens in fostering agricultural development in many tropical countries, usually achieved with very small staff and slender financial resources, is now often forgotten.

MOVEMENT OF CROPS IN THE TROPICS

I have already shown how botanic gardens played a prominent role in the distribution of the principal economic crops grown today in the tropics. It is worth examining the subject a little further. It has always seemed strange to me that many of the world's major tropical plant products are produced largely in countries far removed from their region of origin, e.g. South American rubber in Malaya and Indonesia, South American cacao in West Africa, South American quinine in the East Indies, African coffee in Brazil, cloves and nutmegs from the Moluccas in Zanzibar and Grenada respectively, sugar, bananas and limes from South East Asia in the West Indies, and vanilla from Central America in Madagascar. Obviously this cannot be attributed to any one particular reason and many factors are involved, including economics, available land and labour supply, technical skill in processing, suitability of the crop for plantation or peasant agriculture, etc. Nevertheless, one would have expected that a crop was more suited ecologically to its country of origin than to its new home. I suspect that one of the major reasons is that when a new crop has been introduced without many of its normal pests and diseases, it has more chance of flourishing and giving high yields. Many of the crops are introduced as seeds, which limits the number of pests and diseases which they can carry with them, and this is further enhanced by the plant quarantine regulations now enforced in many countries. One can only contemplate what would happen to the Malayan rubber industry if the South American Leaf Blight (*Dothidella ulei*) were accidentally introduced.

In this digression I have limited myself to economic crops, but further examples can well be given from food crops, too. Many of the staple crops now grown in parts of tropical Africa are of New World origin, e.g. cassava, sweet potatoes and maize.

THE EARLY PENANG BOTANIC GARDENS

Ridley (1910a) gives the date of the founding of the first Botanic Gardens, Penang, as 1800, although in the same article he states that, soon after the

first settlement in Penang in 1786, the East India Company decided to start spice gardens with a view to breaking down the Dutch monopoly of the spice cultivation and trade. A botanist, Christopher Smith, was appointed in 1794 and in 1796 was sent to the Moluccas to collect living plants of nutmegs and cloves. Ridley then adds that by 1800 the Gardens contained 1300 plants and that they were greatly enlarged in that year, when 15,000 clove and 500 nutmeg trees arrived from Amboina. It thus appears that the first Gardens were begun about 1796 and not in 1800 as is usually stated. Ridley goes on to say that Smith sent in all 71,266 nutmeg plants, 55,264 cloves and large quantities of canary nut (*Canarium commune*) and Kabong palm (*Arenga saccharifera*).

This transporting of very large quantities of plants in the tropics was to continue throughout the nineteenth century. Nor was the movement confined to economic crops, as plants of horticultural merit were freely distributed between botanic gardens, while scientific institutions, wealthy patrons, seedsmen and nurseries sent collectors to the far corners of the earth to bring back novelties for their hothouses and for sale. The scale on which the exchanges took place is hardly conceivable today and the expense, difficulty and length of time spent transporting them must have been very considerable.

The first Penang Botanic Gardens were sold in 1806. Raffles founded the second Gardens in Penang in 1820. Ridley states that these existed until 1834, ' when Governor Murchison, who took no interest in gardens or agriculture, sold them for 1250 rupees, because his wife could not get enough vegetables from them to diminish her cook's bill '.

HISTORY OF THE SINGAPORE BOTANIC GARDENS

The Singapore Botanic Gardens are the last gardens in the British tropics which function as a separate and self-contained department and have never been under the control of any Agricultural Department, Municipality or University. I now propose to confine my attention to these Gardens and describe some of the work carried out there during their long history.

THE FIRST SINGAPORE BOTANIC GARDENS

Shortly after the founding of Singapore in 1819, the founder, Sir Stamford Raffles, started the first Botanic Gardens on the Government Hill at Fort Canning in 1822. Nathaniel Wallich, who was visiting Singapore from the Calcutta Botanic Gardens, advised on this project. Raffles introduced nutmegs, cloves and cocoa. These gardens were closed in 1829 on instructions from India to retrench expenditure. They were re-opened later by an Agri-Horticultural Society in 1836, who covered the cost from the sale of nutmegs and cloves growing there. They were finally abandoned about 1846. The principal crops of Singapore at that time were nutmegs and gambier; the former failed because of pests and diseases; the latter was too exhausting to the soil and required large quantities of charcoal for its preparation.

In a recent popular article in a Singapore paper a writer (H.T.S., 1956) says, ' When critics carp at British colonialism, they should stop for a moment and ponder on the odd circumstance that one of the first matters which

occupied the earnest attention of the founders of Singapore was to find a site for a botanical (*sic*) gardens. No great plan for exploiting the local people was afoot here '.

THE SECOND SINGAPORE BOTANIC GARDENS

The first phase: 1859–1875

In 1859 a new Agri-Horticultural Society was formed in Singapore, the third in the history of the island. The Society was given a grant of some 60 acres of land in Tanglin by the Government on which to found a garden. Convict labour was also provided. Members of the society paid an entrance fee and a monthly subscription, while there were second-class subscribers who might enjoy the use of the gardens by paying a monthly fee. They also raised money by public entertainments. The southern end of the Gardens was probably abandoned gambier land, a haunt of tigers, while the north was still virgin tropical evergreen rain forest, 11 acres of which are still preserved in their original form, a most valuable asset in the centre of a great city. The first object of the committee was to create a pleasure garden with roads, terraces and a band stand, where military bands performed fortnightly, the gardens providing an alternative evening drive to the Esplanade for ' the quality '.

Laurence Niven, who supervised a privately owned adjoining nutmeg plantation, was employed part-time as Superintendent. He had a fine eye for design and laid out the Gardens much as they are today. As early as 1861, flower shows were organized in the hope of encouraging the local cultivation of vegetables, fruits and flowers. In 1866 the Society purchased a further 25 acres of land and built the present Director's house, as well as constructing the Gardens lake. This depleted the Society's funds and in 1869 they approached the Government for a further grant, the first being $50 towards Niven's salary in 1866. The second grant was agreed to on condition that the Society should exhibit in the gardens living economic plants. At the same time a small zoo was started. (There has been a menagerie at the Jardins des Plantes in Paris since 1794.) By 1874 the Society was in debt and could carry on no longer. They asked the Government to take over their Gardens and their debts and to maintain the Gardens for the benefit of the people of Singapore. Government agreed to do this and in 1875 the management committee asked Sir Joseph Hooker, the Director of the Royal Botanic Gardens, Kew, to recommend a suitably trained candidate for the post of Superintendent, who 'was to be a practical, as well as systematic, botanist, and to travel in the Malay Peninsula not a little for the purpose of investigating its vegetation ' (BURKILL, 1918).

Thus the second Singapore Botanic Gardens, which celebrates its centenary in 1959, originating as a little more than a public park, began the second phase of its history and was changed into a working Botanic Garden.

The second phase: 1875–1888

Sir Joseph Hooker sent out James Murton, a Kew-trained horticulturist. He was energetic and enthusiastic, but unfortunately was very young and little suited for control. He added greatly to the collection of plants growing in the Gardens, both economic and horticultural, from the principal

Botanic Gardens in the East, as well as Kew. Kew sent the first live Para rubber seedlings in 1877 (see below).

Under the Raffles Society Ordinance of 1878 the Gardens were legally taken over by the Government of the Colony and vested in Her Majesty the Queen, her Heirs and Successors. In 1879 the Government allocated a further 102 acres of land, now occupied by the University of Malaya, for the cultivation of economic crops, particularly gutta-percha and rubber-producing trees. Also growing in these Economic Gardens at this time were *Cinchona*, arabica and liberica coffee, *Eucalypti*, *Ipecacuanha*, tea, maize, sugar cane, cola nuts, mahogany, etc. Murton added greatly to the Gardens menagerie. He collected plants in Singapore and in the Peninsula, but his duplicates in Singapore later disappeared, when he was dismissed in 1880. He died in Bangkok the following year and Burkill (1918) says 'his death was perhaps hastened by his having burnt the candle at both ends'.

Murton was succeeded by Nathaniel Cantley, who was also a Kew-trained horticulturist. He had been Assistant Superintendent of the Mauritius Botanic Gardens and was an older man, a great lover of order. He did much planting and named and labelled all the plants in the Gardens. He surveyed the forests of the Straits Settlements and was responsible for gazetting the first forest reserves. He planted large numbers of Malayan and introduced timber trees in the Economic Gardens, and his arboretum was arranged in a botanical sequence on the system of Bentham and Hooker. Cantley was a keen botanist; he collected local plants and started the herbarium. He also experimented with European vegetables. The grounds of Government House Domain were placed under the Botanic Gardens and still remain so today. The Gardens also helped in horticultural work in the city and much of the tree planting in Singapore, which greatly adds to its attraction, was supervised by the Gardens staff. Cantley founded the Waterfall Garden in Penang in 1884 and these gardens were to remain under the supervision of the Singapore Botanic Gardens until 1946. Cantley, who had never been a very fit man, went on sick leave in December 1887 and died the following year.

The third phase: 1888–1912

With the appointment of Henry Nicholas Ridley as Director in 1888 the Gardens entered upon the third stage in their history and a most productive period it was. 'Ridley's capability as a research worker and his power to demonstrate by his publications the practical and beneficial effects of phytography on plant science in all its aspects . . . succeeded in a surprisingly short time in pushing the Singapore Gardens to the fore as a centre of Malaysian phytography' (DE WIT, 1949). Ridley was a tireless worker and his phenomenal output of work in the natural sciences and his application of this to economic problems is quite remarkable.

He has been rightly named 'the father of Malaya's rubber industry'. His early experiments on the tapping and preparation of rubber and his constant advocacy of it as a plantation crop, often in the face of opposition, led to the foundation of the present industry upon which so large a share of the wealth of Malaya and the eastern tropics has rested (PURSEGLOVE,

1955a). Nor was his work on economic crops confined to rubber; he carried out experiments with most of the actual and potential crops known. As early as 1889 he reported that cacao would probably be profitable on the better Malayan soils, while in 1907 he directed attention to the possibility of oil palms as a plantation crop. The local planting community was largely dependent upon the Economic Gardens for planting material and seeds of economic crops were distributed to all parts of the tropics. In the case of rubber alone, over nine million seeds were distributed from the Singapore Botanic Gardens, as well as many seedlings. The Gardens obtained a considerable income from the sale of these, as well as the rubber produced, thus allowing them to be maintained without any increase in Government vote. Visitors from all over the world visited the Economic Gardens, while Ridley and his three assistants, in Singapore, Malacca and Penang, were the only trained men whom the planting community could approach for technical advice and help. It was Ridley who was responsible for and then administered, the *Coconut Trees Preservation Ordinance* of 1890 for the control of the rhinoceros beetle. In addition to being Director of the Botanic Gardens, Ridley was also Director of Forests, Straits Settlements, and was responsible for gazetting additional forest reserves. He produced the first published accounts of Malayan timbers, vegetables, fruits, fibres, dyes and drug plants, while his book on *Spices* (1912) is the standard work.

Ridley's work as a field botanist is equally remarkable. He travelled far and wide in the Malay Peninsula, often in remote regions, as well as visiting Cocos and Christmas Islands, Borneo, Java and Sumatra. On all these expeditions he studied the vegetation and brought back vast numbers of herbarium specimens, as well as many living plants for trial in the Gardens. In all he collected many thousands of specimens, of which a large number were unknown to science. These specimens are now in our herbarium, but duplicates were sent to Kew and other botanical institutions. He named and described for the first time a few thousand plant species and a surprising number are still only known from his original gatherings. Specimens were sent to experts on certain groups elsewhere and many new species were named in his honour. Ridley realized very early in his career that the flora of a country cannot be studied *in vacuo* and that it is essential to take into account plants from neighbouring territories as well. After his retirement he wrote his five-volume *Flora of the Malay Peninsula* (1922–25).

Nor was Ridley's attention confined to plants, which he collected in all groups. He belongs to that great pre-specialized age of scientific natural history and he collected and studied many animals, as well as distributing specimens and writing about them. Ridley's work as a naturalist has been more fully described elsewhere (PURSEGLOVE, 1955b). He took a keen interest in the Gardens menagerie, which was disbanded in 1904–5, much to Ridley's obvious regret.

In addition to publishing in many scientific journals in Singapore and overseas, Ridley founded the *Agricultural Bulletin of the Malay Peninsula* in 1891, so that he could supply the planting community and others with information resulting from his many investigations. In all he published over 500 papers, articles and books, totalling over 10,000 printed pages,

so that the work of the Singapore Botanic Gardens became widely known throughout the world. Details of his publications and other work will be found in *Gardens' Bulletin* **9** (1935) which was dedicated to him on his 80th birthday. Attention should be drawn, however, to his encyclopaedic volume, *The Dispersal of Plants throughout the World*, published in 1930, which still contains much of value for the botanist and the agriculturist.

Few people have accomplished so much in twenty three years of tropical service as Ridley did—he retired in 1912—nor have completed their work after retirement as he did. He was elected a Fellow of the Royal Society in 1907 and, apart from the honour of C.M.G. in 1911, he received comparatively little public recognition, until his hundredth birthday, which was celebrated on 10 December, 1955. On this occasion he wrote ' It is a great delight to me to have lived to see the Gardens, the best tropical Gardens in the world ', and that ' my hundredth birthday was one of the most enjoyable days of my life '. It is with regret that I record the death of Mr Ridley on the 24 October, 1956.

The founding of Malaya's rubber industry—Accounts of the transfer of Para rubber from Brazil to the eastern tropics have often been given, but frequently they are inaccurate in detail. As the Singapore Botanic Gardens played such an important part in this introduction, it is worthwhile recording briefly the facts at this juncture.

Sir Clements Markham of the India office, who had been responsible for bringing *Cinchona* from South America to the east in 1865, pointed out in 1870 that there was a danger of exhausting the South American supply of wild rubber and recommended that plantations should be put down in the east. James Collins, who was Government Economic Botanist and Librarian in Singapore, was asked to collect all the available information about rubber-producing plants and his report was published in 1872. Through Markham's efforts and those of Sir Joseph Hooker, the Director of Royal Botanic Gardens, Kew, a few seeds were collected and sent to Kew in 1873, when a dozen plants were raised. Six of these were sent to the Calcutta Botanic Gardens and were later propagated and sent to Sikkim, where they were a failure, the climate being unsuitable. A consignment of seeds was sent to India in 1875 and failed to germinate.

Markham then arranged for Robert Cross to collect rubber seeds in South America, while Hooker obtained the services of H. A. Wickham, later Sir Henry, who was then on the Amazon. Wickham collected 70,000 seeds. He did not smuggle the seeds out as is often suggested; it is now known that they were brought out with the goodwill and cooperation of the Brazilian Government. Wickham chartered a ship and the seeds arrived at Kew on 15 June, 1876, where they were planted immediately. Less than 4 per cent germinated and some 2800 seedlings were raised at Kew. Many large tropical oily seeds retain their germination powers for short periods only and it was Ridley who later discovered that they could easily be transported in damp powdered charcoal. On 9 August, 1876, Kew sent 1919 plants to Ceylon in 38 Wardian cases. Two days later 50 plants were sent direct from Kew to Singapore. THISELTON-DYER (1878), later quoted by RIDLEY (1910b), states that ' owing to the delay in payment of freight (in Singapore) these plants all perished '. BURKILL (1935) says

that Murton reported that 'five plants were alive when the cases were received at the Gardens', although they appeared to have perished subsequently. On 10 June, 1877 Kew sent a further 22 plants direct to Singapore and these thrived. They were not sent from Ceylon as is often published.

Figure 1. Mr H. N. Ridley with one of the original rubber trees in the economic section of the Singapore Botanic Gardens, ca. 1902. The last of the original trees was cut down when Raffles College took over this section of the Gardens in 1925

In the meantime Cross returned to England with a consignment of plants in November, 1876. BURKILL (1935) states that 'not one of Cross's plants collected in Para is known to have survived the seedling stage or to have reached the east'. This was good fortune in disguise as the east was stocked from Wickham's seeds, which were collected in the central valley of the Amazon, where the trees are now known to have been of better quality than those nearer the mouth. Murton planted twelve of the rubber plants near our present nursery and then in 1879 transferred them to swampy ground in the new Economic Gardens, as it was thought that this was the natural habitat of the tree. He took nine of his seedlings to Perak in October, 1877 and these were planted at the Residency at Kuala Kangsar. Most of the rubber in Malaya has come from this original introduction, although some seeds were received from Ceylon at a later date.

The Singapore trees first fruited in 1881 and were greatly increased by Cantley, so that when Ridley arrived in 1888, there were 'over a thousand full-grown trees' in the Economic Gardens. The subsequent exploitation and establishment of rubber as a plantation crop in Malaya was due almost entirely to Ridley. Within four months of his arrival in Singapore he

drew the Government's attention to this possibility. With great perseverance, little encouragement or help and slender financial resources, he set to work. He has since recalled how he was 'carpeted by the Governor, Sir Frank Swettenham, who admonished him to waste less time on an uneconomic product such as rubber'. He experimented with various rubber-producing trees and found that *Hevea* was superior to all others. Starting with a mallet and chisel, and later using a modified farrier's knife, he developed the tapping technique which has been but little changed since. He discovered wound response, which he terms 'calling the rubber'. and he also demonstrated that the bark regenerated and could be tapped again. He exhibited coagulated rubber in Singapore in 1890 and the following year sent specimens to England which were well reported on.

Having shown that rubber was a commercial proposition. Ridley then tried to persuade the reluctant planters to give the new crop a trial, but at first met with little success, as coffee was considered to be the only important crop in Malaya. For his efforts he was known as 'Mad Ridley'. In 1893 he distributed the plants and seeds to Residents and District Officers in the Federated Malay States to plant near their houses. It was fortunate for Malaya that when rubber planting began in earnest—coffee prices had slumped and the trees had been attacked by diseases and pests —there was at the Singapore Botanic Gardens a good supply of planting material and Ridley, the expert, with the latest 'know-how' to advise and to help planters. Ridley stayed long enough in Singapore to see the great rubber boom in 1910 and for Malaya to reach the predominant position in world rubber production, which it has never lost.

The fourth phase: 1912–41

During Ridley's term of office the Gardens established for themselves an international reputation, which was adequately maintained during the next stage in their history. With the forming of the new Agricultural Department in 1904, much of the work on the economic crops passed from the Gardens and the Economic Gardens were finally closed in 1925. Gradually during the period more staff were recruited, especially botanists, so that the work on taxonomy could be extended. Some work was done on the lower plants, particularly the Fungi. In the horticultural field the hybridizing of orchids and other cultigens was undertaken.

I. H. Burkill, who had been on the staff of the Calcutta Botanic Gardens and had collaborated with Watt on the study of the economic products of India, was appointed Director in Singapore in 1912. During the 1914–18 war the Gardens were understaffed and there was little time for expeditions and collecting. Anderson's *Catalogue of Plants growing in the Gardens* was published in 1912 and lists 1739 species, which included 276 orchids, 261 ferns and 245 palms. T. F. Chipp was appointed Assistant Director in 1915, a new post having been created, but he did not take up his duties until 1919. He was transferred to West Africa at the end of 1920, in which year he published his *List of the Fungi of the Malay Peninsula*. Until the Economic Gardens were taken over by Raffles College, now the University of Malaya, in 1924–25, they continued to play an important role in the distribution of economic plants. In 1916 two hundred species were listed

as available for sale at the Gardens. The loss of the Economic Gardens was a grievous blow, as the land available for planting was more than halved.

Burkill continued his interest in medicinal and economic plants generally and collected much information on these in Malaya. He continued this work for 10 years after retirement and published in 1935 his large two-volume *Dictionary of the Economic Products of the Malay Peninsula*, a work of great scholarship, ' a masterpiece of synthesis ', and a model for all works of this type. It is of great value to the botanist and the agriculturist, not only in Malaya, but throughout the tropics. Unfortunately it is now out of print, but I hope that it may be reprinted soon. Burkill also made a detailed study of the genus *Dioscorea* (yams), a genus on which he is still working.

The Gardens Committee ceased to have their own banking account in 1919 and their balance was paid into the Treasury. Thereafter the Government increased the Gardens vote, which was provided under several separate heads, where formerly a lump sum had been given.

R. E. Holttum was appointed Assistant Director in 1922. He was promoted Director in 1925 and continued in this post until 1949, when he became the first Professor of Botany in the University of Malaya. Holttum's principal interests were ferns and monocotyledons and he added greatly to our knowledge of these plants, describing many new species. He showed that wild orchids may hybridize and produce ' species ' which had hitherto never been suspected to be of hybrid origin (DE WITT, 1949). He began work in 1928 on the production of spectacular new free-flowering hybrids of cultivated orchids and this work is still being continued at the Gardens.

C. X. Furtado joined the staff in 1923 and is still Botanist here. During this period he has become an acknowledged authority on the International Rules of Botanical Nomenclature and on Malaysian palms and aroids.

M. R. Henderson was appointed Curator of Herbarium in 1924 and held this post until he was appointed Assistant Director in 1946 and Director in 1949. He worked on Malayan flowering plants generally, his special interest being limestone plants and the family Myrtaceae.

E. J. H. Corner arrived in Singapore in 1929 as Assistant Director, the post which he held until 1946. He specialized in Fungi and trees and carried out research on the morphological and ecological aspects of the vegetation. Corner trained *berok* or pig-tailed monkeys (*Malacus nemestrina*) to collect botanical specimens, thus partly solving the problem of obtaining specimens from tall trees and climbers otherwise inaccessible. Corner states that one of these monkeys knew the meaning of 18 words of Malay and was able to find at the tree tops fruits and flowers which had been shown to him on the ground. It has been said that these botanical monkeys were ' the first apes to enter Government Service '. Corner's two-volume *Wayside Trees of Malaya* was published in 1940, a work full of out-of-the-way information and original observations and is one of the most fascinating books ever produced on the trees of any country. Corner, now Lecturer at Cambridge University, is continuing his study of the genus *Ficus* in Malaysia.

Mention must also be made of C. E. Carr, a Malayan planter, who worked

in conjunction with the Gardens, and added greatly to our knowledge of Malaysian orchids. He died in New Guinea in 1936 when returning from a collecting expedition.

From 1923 to 1939 the senior staff of the Gardens consisted of Director, Assistant Director, Curator of the Herbarium and Assistant Botanist, all actively engaged on botanical research, and three horticulturists as Curators, two in Singapore and one in Penang. In Singapore one Curator supervised the horticultural work at the Gardens and the other looked after Government House Domain and the outside commitments in the City.

The Gardens collection of living plants and the herbarium were added to greatly during this period.

The fifth phase: the Japanese interregnum: 1942–46

During the early years of the 1939–45 war before the Japanese attacked Malaya at the end of 1941, most of the senior Gardens staff were seconded for at least part of their time to the Department of Food Control and Information. The Gardens maintained demonstration plots of vegetables to encourage local production. J. C. Nauen and G. H. Addison, Curators at Penang and Singapore, were mobilized with the local defence force and were later taken prisoners and sent to work on the Siam–Burma railway, where Nauen lost his life. Holttum, Corner and Furtado remained in Singapore during the occupation and were permitted to carry on with their botanical research. Immediately following the capture of Singapore Island, Professor Tanakadate, of Tôhoku University, took over control of the Gardens, and took care that they were not despoiled by the Japanese military forces. Holttum remained in executive charge until the appointment of Professor Kwan Koriba, of Kyoto University, as Director of Gardens in December 1942. During his stay in Singapore Koriba undertook research on the growth-behaviour of some Malayan trees. It was particularly fortunate for the Singapore Botanic Gardens that the Japanese scientific officers and the British staff who remained were able to preserve the herbarium and the library as part of the cultural heritage of Malaya and that no loss whatsoever was suffered in them, except for a few specimens which were on loan in Germany. Losses did occur, however, among the living collection and garden work deteriorated generally, as more than half of the outdoor staff (49 men) were sent to work on the Siam–Burma Railway, where 22 of them lost their lives. There was comparatively little damage in the Gardens, although the Director's house received a direct hit from a shell, but, even so, the damage was not serious.

From September 1945 to March 1946 the Gardens came under the British Military Administration.

The sixth phase: 1946–57

After the war the staff was gradually re-assembled, but did not reach its full complement until the end of 1954. M. R. Henderson was appointed Assistant Director and later Director (1949–54). J. Sinclair arrived in 1948 as Curator of the Herbarium, the title later being changed to Keeper. J. W. Ewart, Horticultural Curator, served as Agricultural Officer, Singapore, as well as carrying out his duties at the Gardens. Henderson retired in 1954 and J. W. Purseglove was appointed Director, while H. M. Burkill

(son of I. H.), was appointed Assistant Director in December of that year.

Gradually during this period the Gardens were brought back to their former good condition, the living collection of plants was increased and collecting in Malaya and Borneo was resumed. The first two volumes by R. E. Holttum of the *Revised Flora of Malaya* were published. Burkill has begun a study of Malayan seaweeds.

On 10 December, 1955 the Gardens celebrated the hundredth birthday anniversary of H. N. Ridley, with an exhibition of Ridleyana and current work, while the Gardens were floodlit for one week. A special brochure for private circulation was produced for the occasion (PURSEGLOVE, 1955c).

Early in 1955 a scheme was drawn up in conjunction with the University of Malaya with the aim of attracting research workers from Britain and elsewhere to Singapore for one or two years to carry out botanical research in their specialized fields. By this means the output of research would be increased and knowledge would be obtained which would be of great value to the tropics as a whole. Furthermore, workers from temperate countries would become familiar with tropical botany and their interest in our problems would be stimulated. In 1955 P. B. Tomlinson of Leeds University was awarded an Agricultural Research Council Scholarship and spent one year here studying the anatomy of palms. T. C. Whitmore, a Ph.D. student of Cambridge University, arrived in December 1956 to spend a year working on the anatomy of Dipterocarp barks in relation to taxonomy. He is receiving a Colonial Development and Welfare grant. It is hoped that more research workers may come in the future.

Waterfall Garden, Penang—The third Botanic Gardens in Penang were founded by Cantley in 1884 as ' a nursery for the planting of colony products ', and were under the charge of the Gardens and Forest Departments, Straits Settlements, with its headquarters at the Singapore Botanic Gardens. Charles Curtis, who had been employed as Messrs Veitch's plant collector in Mauritius, Madagascar and Malaysia, was appointed Superintendent and remained there until his retirement in 1903. HOLTTUM (1934) records that Curtis ' was an enthusiastic plant-lover and a born gardener, and the development of the Waterfall Garden is a monument of his energy and skill '. Curtis also made large collections of herbarium specimens in Northern Malaya. The Penang herbarium was later incorporated with that at Singapore.

In 1910 it was decided to convert the Gardens into a reservoir, but fortunately this did not materialize. With the formation of the Malayan Union in 1945, later renamed the Federation of Malaya, and the separation of Singapore as an individual colony, the control of the Waterfall Gardens passed from the Singapore Botanic Gardens to the Federation Agricultural Department. This was a great loss to the Singapore Gardens as the climate of Penang is more seasonal than that of Singapore and was therefore better suited for the growth of certain plants, which flower and fruit there, but will not do so in Singapore. Furthermore, the Penang Gardens lost the stimulus of direct contact with the parent institution where botanical research is carried out.

THE WORK OF BOTANIC GARDENS

The principal work carried out by botanic gardens can be divided under three broad heads, namely, botanical, horticultural and educational, although inevitably there is some overlapping between them. In addition to these functions most botanic gardens are opened to the public and thus provide the facilities of a public park. For this purpose they should be laid out as attractively as is possible, without jeopardizing the work of the scientific study of plants. The Singapore Botanic Gardens are opened to the public from 6 a.m. until 7 p.m. daily; no charge is made and the popularity of the Gardens can be gauged from the very large number of visitors to them. Most tourists visiting Singapore also come to see the Gardens.

I now propose to give a more detailed account of the work under the various heads given above, illustrating this from the Singapore Botanic Gardens.

BOTANICAL WORK

The living collection

A botanic gardens should have as large a collection of living plants as it is possible to grow, without sacrificing an attractive layout. In fact a Gardens should be a great museum of living plants. All the plants should be correctly labelled with their scientific name and family, together with the country of origin. If there is a common English or vernacular name, this may be added, but this is often difficult when various languages are spoken as in Singapore. Care should be taken to keep the names up-to-date according to the latest nomenclature changes. As many different groups of plants as possible should be represented. Inevitably, certain gardens specialize in certain groups, particularly those on which specialists have been working. Thus in Singapore our collections of palms, orchids and ferns are particularly good. Inevitably many plants of botanical interest, but of little value horticulturally, must be included in a botanic gardens, and they are not always as colourful as the layman expects. It is desirable that closely related species or even groups should be planted near each other, which is very useful for comparative purposes, but this should not be carried to the extreme, as it results in a deterioration in the lay-out. Herbs and woody plants of varying stature, although belonging to the same family, are often difficult to grow together and to maintain and are unsightly when so planted. A great many plants can be grown in pots. For this a burnt earth-compost mixture has proved to be the most suitable for our conditions for many plants. This method is described by HOLTTUM (1953a).

The Singapore Botanic Gardens have some 3000 perennial species growing in them at present and this does not include hybrids. Even so, there is a limit to the number of plants that can be grown in our 85 acres and there is little room for further planting, particularly of large trees. The work of labelling such a large collection presents difficulties and label printers are constantly at work repainting old labels and preparing new ones. The majority of our labels are made of wood or metal, 6 in. × 4 in., with an iron prong 8 in. long for sticking into the ground. They are painted black with the plant name clearly printed in white. For pots and small species printed

aluminium labels are used. These are also attached to trees in the Gardens Jungle, but unfortunately they are often removed by monkeys.

The herbarium

In addition to the living collection, a botanic gardens should have a *hortus siccus*—the herbarium, or at least one reasonably accessible to it. In this, dried mounted specimens are preserved. The Singapore Herbarium is situated in the Gardens and has over 400,000 sheets. The specimens are mainly confined to plants of the Malaysian region, which extends from Sumatra and Malaya to New Guinea, but there are a few from surrounding countries. Our oldest specimens are over 150 years old and are still in a

Figure 2. Part of the living palm collection of the Singapore Botanic Gardens

good state of preservation, despite the fact that they are housed in wooden cupboards and the building is not air-conditioned, although the latter is preferred if possible. The collection is arranged according to the Bentham and Hooker system, and, within the species folders, according to the various Malay states, Malay islands and exotics. There is also a smaller and separate Gardens Herbarium of cultivated plants.

In addition to being in constant use by the botanists, both at the Gardens and the University, the specimens are sent on loan to botanical institutions elsewhere for study. In 1956 a total of 4525 sheets were sent on loan, mainly to Leiden, Bogor and Kew, to authors of the *Flora Malesiana*, while 4903 sheets were sent on loan in 1955. The value of the specimens is enhanced considerably when the sheets are returned correctly annotated. Inevitably some mixing occurs in folders until the genus has been currently revised, but this is not peculiar to Singapore.

There is also a good collection of spirit material, particularly of orchids, and this is invaluable for detailed study.

Collecting, naming and distributing specimens

Both the living and dead collections of plants at the Botanic Gardens are added to constantly by collection, donations and exchange. Plants do not recognize political boundaries and in studying the plants of a country such as Malaya, it is essential to study the plants of surrounding countries, if one is to understand the variation and distribution of the local species. Thus botanists from the Singapore Botanic Gardens, although the bulk of their collection has been done in Malaya, have also collected extensively in Borneo and to a lesser extent elsewhere, where the flora shows regional affinities. We also try to collect as many duplicates as possible of each gathering, so that these may be distributed to other institutions elsewhere. In these uncertain days spatial separation of duplicates is very desirable, so that if one or more sets are destroyed, as happened in Berlin and the Philippines during the war, others are available elsewhere. 5397 duplicates were distributed from Singapore in 1956, many of which were plants collected by the writer in Sarawak. 6768 duplicates were received, of which a large portion came from the Forestry Departments of Sarawak, Brunei and British North Borneo. Many of these were unnamed and have since been determined by the staff. Private collectors are also encouraged to send in specimens.

The importance of adequate field data on all specimens cannot be overstressed. Each specimen should be given a serial number and notes are made of the place of collection, habitat, altitude, relative abundance, as well as information on habit, colour of flowers, etc., which cannot be ascertained from the dried specimens. Special herbarium labels are provided for listing these data. In the past this type of information, which can be of very great value to the taxonomist, was frequently neglected. Sterile material is often of doubtful value.

With the aid of a good modern flora, a botanist should be able to determine most of his specimens in the field—but unfortunately how many tropical countries have complete up-to-date floras ? Even when they are available, certainty can only be reached by comparison with authentic named material. Agricultural and forestry departments, teachers, students, planters and others from Malaya, Borneo and elsewhere send us specimens for determination. Small plant fragments are sometimes sent for identification in connection with police investigations, medical inquiries, etc. We receive frequent requests for information on certain plants. Thus we provide an important service, which cannot be obtained elsewhere in Malaya.

Taxonomic studies

A very important function of any botanic gardens is research in systematic botany. This critical and highly specialized work involves detailed revisions of genera and families and is an essential preliminary to the publication of any flora. Previously named species are critically examined, questions of synonymy are finalized, and new species are described. Furthermore such work can never be completely perfected, as a critical study of the great

amount of material collected during the past 40 years reveals large numbers of undescribed species, as well as new information on distribution and variability, while future collecting will yield yet more. It is necessary that the names and descriptions of Malayan plants should be brought into line with those of neighbouring countries. I am convinced that a study of Malaysian plants as a whole is an essential preliminary in the preparation of the local flora. Consequently, the staff of the Singapore Botanic Gardens is now collaborating in the production of the *Flora Malesiana*, edited by C. G. G. J. van Steenis of Leiden University and financed by the Indonesian Government. This major work will occupy many botanists from many countries for many years.

So much new material and new knowledge has accumulated since the publication of Ridley's *Flora of the Malay Peninsula* in 1922–25, that it is now out-of-date and a *Revised Flora of Malaya* is being prepared. Two volumes have been published so far, both by R. E. Holttum, namely, *Orchids of Malaya* (1953) and *Ferns of Malaya* (1955). This work is designed to be of use to the field naturalist and the gardener, as well as the specialist, and includes introduced, as well as indigenous, plants.

The great complexity of the Malaysian flora, which is one of the richest in the world, makes the task of the taxonomist a very formidable one. Some idea of this can be obtained if one realizes that the island of Singapore, with an area of 225 square miles and a population of one and a quarter million, has some 2000 indigenous species of plants, a total which is greater than that of the British Isles; the Malay Peninsula has about 10,000 species, while the estimate for the Malaysian region as a whole is 30,000 species.

The taxonomist working in the region whose flora he is describing has the great advantage of being able to study many of the plants in his group living in their natural habitat, which is an invaluable aid to his study of herbarium material. Some of the plants may also be growing in the local botanic gardens. For modern taxonomic study it is essential for the worker to see as many as possible of all the collections that have ever been made of the species he is studying. Thus most herbaria are willing to lend their specimens to experts wherever the latter may be working.

The importance of taxonomic research

The great Linnaeus has said ' Science, and in the first place botany, is the only reliable basis of private as well as national economy '. Many people would regard this statement as too sweeping; nevertheless taxonomic research is of vital importance to the agriculturist, the forester and other applied scientists, as well as all those who wish to assess and develop the natural resources of a country. Many people fail to realize the importance of giving plants their correct scientific names, so that their results can be understood in all countries regardless of the language used. Their research would often be of greater value if they took the trouble to ascertain the correct names of the plants they are working with, and, in the case of plants not widely known, would lodge authentic specimens at some recognized institution for reference purposes. Anthropologists and others frequently write of plants used by indigenous people as food and medicine and in magic, etc., and are content to give the vernacular names only, thus rendering

their work nearly worthless for the botanist, chemist and others, who might well follow it up had they taken the trouble to collect specimens and get them properly identified. I have long felt that there is far too little active collaboration between the agriculturist and the botanist to their mutual disadvantage.

The knowledge of the correct names of plants is essential for the ecologist. I would like to see the collecting numbers of plants quoted in ecological papers, so that future workers have access to the specimens on which authors have based their results. Some ecological studies have been carried out by the staff of the Singapore Botanic Gardens in the past and I would like to see this extended. I believe that ecological studies in the widest sense provide the only sound bases for the preparation of rational plans of land utilization.

Botanists from their collections and research discover plants which are closely related to those in cultivation and thus can provide material of great value to the plant breeder. An Indian sugar-cane breeder visited Singapore in 1956 and found in our herbarium one sheet of a varitey of *Saccharum spontaneum*, which had been collected by Ridley in 1891 in a remote area of Penang. Travelling by plane, car and boat he was able to obtain planting material of the variety and returned to Singapore within four days.

This section could be extended considerably. I hope I have said enough to convince the Philistines that the plant collecting and taxonomic research carried out by the staff of botanic gardens has a wider application than is often realized.

HORTICULTURAL WORK

Exchange of planting material

Most botanic gardens produce an annual *Index Seminum*, or seeds list, which they distribute to other botanic gardens for favour of exchange. As the number of species of which seed is available in Singapore varies but little from year to year, our list is produced at irregular intervals for distribution and is also available on request. We receive lists from all over the world, including most Communist countries. In this way a free exchange of planting material is effected, thus enriching the living collection of plants in all countries. In 1955 the Singapore Botanic Gardens sent out 515 packets of seeds and 113 plants on an exchange basis and received 362 packets of seeds and 371 plants, including gifts. 368 packets of seeds and 87 plants were despatched in 1956, while 575 packets of seeds and 185 plants were received. Only a small proportion of the introductions may be really successful in Singapore; nevertheless, our collection of plants is being added to constantly and new plants of horticultural value are available for the country as a whole.

The immediate supply of seeds from the Singapore list cannot be guaranteed as many local seeds are viable for short periods only and stocks cannot be kept in good condition, while many species fruit at irregular or long intervals. Every effort is made to meet requests, however, and lists are kept of requirements and the seeds are collected and despatched at the earliest opportunity as they become available. Our current list gives 864 species, some of which are grown in the Gardens, while others are collected

in the natural vegetation on the island. Many of the larger seeds of short viability are sent out in damp powdered charcoal or damp coir dust. Germination begins during transit and we receive very favourable reports on palms and other seeds sent out in this way.

In addition to this normal exchange of seeds between botanical institutions, many requests are received for living plants, as well as spirit and fixed material, from specialists elsewhere. Wherever possible it is provided, except for unreasonable requests which would require a major expedition to fulfil or take up too much time. In all this exchange care is taken to see that only authentic material is sent out.

During the past few years a collection of over 400 species of cacti and other succulents has been built up. These grow surprisingly well in Singapore, provided they are sheltered from the rain and receive plenty of sun. They are grown in open-sided houses with glass roofs. Succulents are becoming very popular among local growers.

Members of the staff on collecting expeditions bring back local plants of horticultural value for trial in the Gardens, while friends and correspondents send in similar material. Living material is usually packed in polythene bags, in which it remains fresh for a considerable period. One of the most successful introductions in recent years has been the New Guinea Creeper (*Mucuna bennettii*), which produces hundreds of large spectacular trusses of brilliant flame-coloured flowers several times a year.

Although most of the work on economic plants has been taken over by the Agricultural and Forestry Departments, there is still a good collection in the Singapore Botanic Gardens and new ones of special interest, such as *Rauwolfia* spp., are introduced for trial.

Breeding of orchids and other plants

The seasonless climate of Singapore, with an average annual rainfall of 105 inches per year, a mean temperature of about 80°F with little diurnal change and a mean relative humidity of 82 per cent, makes it difficult to find plants which will flower regularly and provide colour in the Gardens. The aspect of the natural vegetation is varying shades of green and offers little in the way of good horticultural plants. Consequently, most of the garden plants grown in Singapore have originated in countries other than Malaya and where there are distinct cold or dry seasons. Under our conditions there is no special season of flowering or leaf-fall and individual plants of the same species adjust themselves quite differently. Consequently, we never get the spectacular bursts of flowering of such trees as *Delonix regia* or *Jacaranda* as can be seen in India or East Africa.

One of the solutions to this problem is the breeding of new varieties of plants suited to local conditions and this work has been actively pursued at the Singapore Botanic Gardens for many years. Although hybridization has been done in various groups such as *Bougainvillea*, *Canna*, etc., by far the most attention has been devoted to orchids. This work was begun in 1929 and has produced very successful and spectacular results. The aim is two-fold, namely, to produce hybrids of horticultural merit and commercial worth and to investigate the relationship between the various groups of orchids. Malaya has some 800 species of indigenous orchids, but only a

few of these are suitable for garden plants. By hybridizing them, together with imported species from Burma, Java, the Moluccas, New Guinea and the Philippines, a very wide range of free-flowering and beautiful hybrids has been and is being produced.

The principal genera used in crossing are: *Arachnis*, *Dendrobium*, *Renanthera*, *Spathoglottis* and *Vanda*. The first Singapore hybrid was Vanda Miss Joaquim raised in 1893, but most of the hybrids now grown have been

Figure 3. Orchid seedlings growing on a sterilized medium in the laboratory of the Singapore Botanic Gardens. (Photograph by courtesy of G. H. Addison)

produced in the last 30 years and many of these since 1945. Some 2800 crosses have been made to date and every year new hybrids are coming into bloom. Local growers also make crosses and bring their seeds for raising at the Gardens, while a few have now mastered the technique and raise them themselves.

The seedlings are first grown in conical flasks under sterile conditions. The medium used in Singapore is agar-agar with Vacin's solution and 2 per cent sugar, at a pH of about 5·2. Full details of the method are given by Holttum (1953b). In 1956 experiments were begun using coconut milk (the water inside the mature nut) in the medium and this is giving a considerable stimulus to the early growth of the seedlings. The mature orchids are grown in the open or with slight shade, either in pots or in beds, depending on the type, and details of the cultivation can be found in Holttum (1953b) and Henderson and Addison (1956).

Mention can only be made of one or two of the hybrids raised in Singapore. A fuller account of the principal hybrids, except for the very recent ones,

with photographs of a spray and individual flower of each hybrid, has recently been published in HENDERSON's and ADDISON's *Malayan Orchid Hybrids* (1956). Vanda Tan Chay Yan, which first flowered in 1952, was awarded a First Class Certificate of the Royal Horticultural Society at the Chelsea Flower Show in 1954 and is considered to be one of the best Vanda hybrids bred anywhere in the world. Arachnis Maggie Oei, now one of the principal cut flowers in Singapore, flowers continuously, whereas its larger parent *A. flosaeris* flowers but twice a year. Among the inter-generic hybrids bred in Singapore are *Aranda* (*Arachnis* × *Vanda*), *Aranthera* (*Arachnis* × *Renanthera*) *Renantanda* (*Renanthera* × *Vanda*), while our first tri-generic hybrid flowered in 1956 and has been named *Ridleyara Fascad*, in honour of H. N. Ridley. Mr Ridley was informed of this shortly before his death.

There are many enthusiastic orchid growers in Singapore and the Federation and there is a considerable demand for plants and seedlings grown in the Gardens. The sale of cut orchids, both local and for export, is rapidly increasing. An experienced cytogeneticist is expected to visit Singapore shortly to work on problems of orchid hybridization.

Figure 4. Vanda Tan Chay Yan raised at the Singapore Botanic Gardens and awarded a First Class Certificate at the Royal Horticultural Society Show, Chelsea, 1954

Sale of plants

Although the sale of plants is not an essential function of a botanic gardens, it is desirable in those countries where there are few nurseries. The Singapore Botanic Gardens sells plants daily, but limits the sales to those plants which are not readily available in the local nurseries. The revenue from the sale of plants in 1956 was $27,245 (Straits), of which the major share came from the sale of 3446 orchid plants and seedlings, while 26,092 other plants were also sold.

Advisory work

The horticultural staff of the Singapore Botanic Gardens advise and assist various government departments in planning the layout and planting of roadsides, open spaces, school compounds, etc., and usually supply free material for this purpose. They also maintain close contact with the City Council Parks Department and many requests for advice are also received from private firms and individuals. Thus the Gardens play a large part in beautifying the city and island.

Men from the Rehabilitation Centre of the Labour Department are accepted for training as gardeners. The Director of the Singapore Botanic Gardens is the Imperial War Graves Commissioner's representative in Singapore and the staff of the Gardens take charge of the care and maintenance of the Kranji War Cemetery.

EDUCATIONAL WORK

General

The maintenance of a large, named and labelled collection of local and introduced plants attractively laid out in the Botanic Gardens enables all visitors, who are interested, to increase their knowledge of plants. Parties of school children and students, both from Singapore and from the Federation, pay regular visits to the Gardens and occasionally parties are taken round by members of the staff. Special exhibits are arranged from time to time. One which proved popular with teachers and students was an exhibit of seven common plants which were changed weekly. The plants were labelled with their scientific, English and Malay names and family and brief notes were appended. Members of the staff are often requested to give lectures to local societies, a valuable method of educating the public in our work.

The staff of the Gardens cooperates fully with the staff of the University of Malaya's Department of Botany. The University is adjacent to the Gardens and so the latter are very handy for lecturers and students who wish to use them, while much material is provided for class work and research.

Singapore Gardening Society

The staff of the Singapore Botanic Gardens was largely responsible for the founding of the local Gardening Society, which at present has about 250 members. An active interest is taken in its work, as well as that of the Malayan Orchid Society. Some monthly meetings are held at the Gardens and emphasis is usually placed on practical demonstrations. A very successful annual flower show is held and the standard of blooms and plants exhibited is high. In these ways, the interest of local horticulturists is stimulated and the standard of gardening is raised.

PUBLICATIONS AND LIBRARY

It is very desirable that botanic gardens carrying out research should have their own journal for the publication of their results. Ridley founded the *Agricultural Bulletin of the Malay Peninsula* in 1891. The title was changed to the *Agricultural Bulletin of the Straits and Federated Malay States* in 1900

and it was then issued monthly. This journal was largely devoted to work on economic plants. Ridley published many taxonomic papers in the journal of the *Royal Asiatic Society, Straits Branch*, of which he was editor from 1889 to 1911, as well as being secretary of the Society. The title of the *Agricultural Bulletin* was changed in 1917 to the *Gardens' Bulletin, Straits Settlements* and in 1947 to the *Gardens' Bulletin, Singapore*. This is published at irregular intervals and an attempt is now made to produce one volume per year. It is largely devoted to papers on local taxonomy. It is distributed to the major botanical institutions in the world and exchange arrangements now exist with 160 scientific bodies. It can also be purchased direct from the Botanic Gardens, Singapore. In exchange we receive valuable periodicals and reprints, which are so essential for our work, and which we would not be able to purchase from our slender library vote. The *Annual Report* is also printed and distributed.

In addition to these and other publications already referred to in this article, the Gardens staff prepare from time to time more popular works which are of general interest to the amateur. Such a work is Henderson's *Malayan Wild Flowers* (1949–54) published by the Malayan Nature Society. A series of small illustrated pamphlets, each containing drawings and brief descriptions of ten *Malayan Garden Plants*, are also produced. Popular horticultural articles are submitted regularly to the *Malayan Agri-Horticultural Journal* and the *Malayan Orchid Journal*. Names and descriptions of our new orchid hybrids are published in the latter.

Adequate library facilities are essential for the research workers at botanic gardens. The taxonomist must consult original publications for the names and descriptions of the plants on which he is working, and for this the older, as well as modern, literature is required. The Singapore Botanic Gardens are particularly fortunate in that they have one of the finest collections of old botanical books in South East Asia, many of which are of considerable value and rarity. In all, the library contains some 8000 bound volumes, as well as many periodicals.

Since 1890 there has always been an artist on the Gardens' staff, who prepares drawings and paintings for the specialist staff. The paintings done by James and Charles de Alwis between 1890 and 1908 are of outstanding beauty and accuracy and are among the treasured possessions of the Singapore Botanic Gardens. Over the years a large and valuable collection of plant drawings and paintings has been built up.

NATURE RESERVES

I have already shown how Cantley and Ridley were responsible for gazetting and maintaining the first forest reserves in the Straits Settlement. These were later taken over by the Forest Department. The Singapore forest reserves reverted to the control of the Botanic Gardens in 1937 and have since been maintained as nature reserves. Under the *Nature Reserves Ordinance* of 1951, some 8000 acres in Singapore were 'set aside for the purpose of the propagation, protection and preservation of the indigenous fauna and flora of the Colony', as well as 'providing, under suitable conditions and control, facilities for the study of and research into matters relating to the fauna and flora and the physical conditions in which they

live '. The reserves are administered by a statutory board of management of six nominated trustees, with the Director of the Botanic Gardens as *ex officio* chairman. The day-to-day administration is carried out by the staff of the Singapore Botanic Gardens.

Inevitably, with the spread of the rapidly increasing population, plants and animals, which were known to have occurred in Singapore, have disappeared completely. Every effort is being made to preserve the remnants which are left for present and future generations to study and enjoy. Only a comparatively small area of the nature reserves consists of primary vegetation. The most important is undoubtedly the Bukit Timah Reserve covering 163 acres on the highest hill on the island. It has been a botanical collecting ground for more than a century, and it is the type locality of many Malayan plants. It consists of primary tropical evergreen rain forest, with many trees 50–70 m high, and for the greater part it has not been cut or damaged. There are also important areas of mangrove on the south coast preserved as a nature reserve.

Thus the Botanic Gardens have guarded jealously this heritage of the people, which might so easily have been lost for ever.

THE FUTURE

And what of the future ? Singapore is shortly to receive independence. Already the Government has embarked upon a programme of rapid Malayanization of its staff, although it is not likely that this will be fully achieved at the Gardens as rapidly as in some other departments. A local man has returned from training as a horticulturist at the Royal Botanic Gardens, Kew, while botanists and others are to be sent overseas for further training and on their return will take over from the expatriate officers. Much will depend on these new recruits to maintain the Gardens and collections and to carry on the tradition of research which has been built up during the past 100 years. It is hoped that the scheme recently devised to attract research workers from Britain and elsewhere to Singapore to carry out botanical research in their specialized fields will be continued and extended.

The Gardens are financed entirely by the Singapore Government and now come under the Ministry of the Chief Secretary. In the 1957 estimates a total of $546,780 (=£63,791) is voted to the Gardens and this includes the votes for the upkeep of Government House Domain and the Nature Reserves. If they are to survive, it will be necessary to convince the politicians and the general public that the Gardens are fulfilling a worthwhile role, not only as a public park, but also in research carried out which is of value to the economy and prestige of Singapore. As Commelijn said in 1701 (DE WIT, 1949) ' It is certain, however, that this Science, like all Sciences, flourishes sometimes more and sometimes less, all in accord with the inclination of Rulers and the Favour of Government '.

A recent distinguished visitor wrote in my visitors' book ' The Singapore Botanic Gardens are unique. Civilization would be the poorer if they were not maintained '. In discussing the history of botanic gardens in the tropics, I have shown how many of them were neglected or abandoned and failed in their primary function, which is the scientific study of plants. New botanic gardens are being founded at some of the new tropical universities

and university colleges, but it will take them many, many years to build up the type of collection of living and herbarium specimens which is now available in Singapore. It is my fervent hope that the Singapore Botanic Gardens may be fully maintained for many long years to come and may continue as a leading centre of tropical botany and a worthy memorial to Ridley and those other members of the staff who have helped to raise them to their present position.

I have shown how in these uncertain and unsettled days there still exists much goodwill and active cooperation between botanic gardens, wherever they may be situated. As Baas Becking says in the Preface to *Flora Malesiana* ' as long as sentiment, politics, greed and bigotry rule this world, a purely scientific endeavour may become a binding force between individual groups, and maybe, even between nations '. If the aims and ideals which motivate the work of botanic gardens could be extended to certain other fields of human endeavour we could make this planet a better place on which to live.

ACKNOWLEDGEMENTS

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Some Aspects and Problems of Sisal Growing in East Africa

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In East Africa sisal is grown under widely differing conditions ranging from the hot and humid coastal belt to the drier and cooler regions of the Kenya highlands. Although the adaptability of the plant coupled with its remarkable drought-resisting powers makes it relatively easy to cultivate on a large scale, nevertheless the production of sisal is not without its problems.

Sisal growing is best carried out on plantation lines and in many respects the set-up of a sisal estate resembles that of sugar-cane. A central decorticating factory is its nucleus and the area and equipment of the estate are geared to the capacity of the factory which may comprise one or two, or even more decorticators. Each decorticator can produce 1500 tons of fibre per annum and this rate has often been exceeded. The area of land required for such an output depends upon soil and rainfall, or factors which affect yields. Generally speaking from 3000 to 5000 acres are needed for each decorticator, a greater acreage being necessary where the rainfall is scanty and growing conditions are less favourable.

The cutting or harvesting of sisal leaves calls for a large labour force in addition to workers for cultivation and other tasks. The leaves are conveyed by light railways, or else by road transport, to the factory where heavy powerful machinery scutches them at great speed. A copious supply of water is needed for washing the fibre which, after drying, is sorted into grades according to length and blemishes. Finally it is 'brushed' in machines in order to improve its appearance and the alignment of the fibres. It is then packed and baled for export.

Like many plantation industries, sisal growing is a monoculture. The amount of green crop reaped per acre is both bulky and heavy but the content of fibre in the leaves may be only 2·5 or no more than 5·0 per cent. Normally yields tend to improve with the age of the plant. Upwards of 40,000 leaves weighing 30 tons or more are obtained from one acre of bearing or 'mature' sisal at each cutting. Cutting proceeds throughout the year and it is usually repeated in cycles of 12 to 18 months according to the rate of growth of the sisal. Both cutting and leaf transport loom large in the daily operations of a sisal estate which needs to be well organized for smooth working. A major problem is the disposal of large quantities of leaf pulp and juices, plus washing water from the decorticator and the usual method is to conduct it along flumes to a dump sited in a valley near the factory.

After giving this thumb-nail sketch of the industry in East Africa, it will be seen that the problems of sisal production may be considered under

three headings, viz. (*i*) agriculture, (*ii*) labour supply and (*iii*) engineering, but it is proposed to confine this article as far as possible to those of an agricultural nature.

VEGETATIVE PROPAGATION

The sisal plant (*Agave sisalana* Perrine) is a monocarpic perennial. After flowering, or ' poling ' as it is termed because of the tall inflorescence, the parent plant dies but perpetuation of the species is doubly ensured by the production of rhizomes or suckers from the base of the plant (particularly when it is young) and later on through the development of masses of bulbils or plantlets on the branches of the pole. Bulbils develop in the axils of bracteoles on the pedicels after the flowers have withered and dropped off as a result of the formation of an abscission layer below each ovary. An important outcome of this characteristic is that sisal is rarely able to set seed and this has helped to preserve the enormous population of plants which is extant in East Africa as a single clone, all derived from 62 surviving bulbils introduced into Tanganyika by Dr R. Hindorf from Florida in 1893 (HINDORF, 1925).

The sisal grower is virtually using one kind of plant so it is unnecessary to select planting material otherwise than for size and uniformity, the exception being to discard any plants having spiny margins since these are usually avoided by cutters. Bulbils and suckers are really bud offsets, thus vegetative propagation of sisal is both easy and prolific. Spiny plants invariably beget their own kind and sometimes plants with smooth, or almost smooth, leaf margins may throw progeny of the spiny type. The reason for this is not understood but in all other respects smooth and spiny plants are identical (DOUGHTY, 1937).

PLANTING MATERIAL

Experimental work at Mlingano has shown that there is no intrinsic difference between bulbils and suckers and that the one kind of planting material will yield as well as the other if everything else is equal. Bulbils, however, require to be raised in nurseries for 12–18 months depending upon rainfall, before they attain a height of 1–1½ feet and are ready for transplanting in the field. Suckers are often large enough to be planted straight away but they are generally very uneven, poorly developed, and etiolated owing to shading and competition with weeds and parent plants in an old plantation. Sometimes they are mutilated by cutting labourers. Properly raised bulbil nursery plants are preferable to suckers on account of their better development and uniformity which facilitates grading for size before transplanting. In addition they grow faster after transplanting and can reach the cutting stage (two or three years later) sooner than suckers. Moreover an even stand of plants simplifies cutting operations later on, especially at the first cutting, besides reducing the work of grading the fibre afterwards since the leaves do not vary much in length once the first cutting has been taken.

Bulbil nurseries entail extra trouble and expense but the value of good planting material cannot be doubted. A well drained fertile soil is essential for successful results and a fairly fine tilth is required. Each bulbil has a rudimentary root system and they quickly become rooted after a few

showers. Trials have shown that close planting is inadvisable and that a spacing of 20 by 10 inches is suitable (LOCK, 1954).

It is not easy to raise nursery plants to the requisite standard within a year if the annual rainfall is less than 40 inches or if it happens to be badly distributed. Under these circumstances overhead irrigation can be a help, although in this connection more practical experience is still required, but mulching with half-rotten sisal waste can also be very effective (LOCK, 1955). Liberal dressings of sisal waste coupled with liming and applications of nitrogenous fertilizers (excluding sulphate of ammonia) enable the same land to be used for several consecutive years without any reduction in the size of the plants due to loss of soil fertility. Permanent nurseries, situated within easy reach of the waste dump if possible, are now being established on estates.

LAND PREPARATION

In recent years hand clearing of virgin bush has tended to give way to mechanical methods. The use of bulldozers, however, is to be condemned utterly owing to the immense amount of damage caused through excessive movement of topsoil.

Heavy rippers and ploughs drawn by large diesel crawler tractors are often used to remove a tangle of bush roots in the soil but secondary regeneration of bush is usually considerable. In this particular, research work with arboricides is being prosecuted.

The clearing of old sisal fields having thousands of old boles, like giant ninepins, used to be laborious and expensive. But nowadays heavy rollers fitted with knives, known as bush breakers, are used for crushing and disintegrating the vegetation and they have proved to be most effective and labour-saving. Burning is no longer necessary and the flattened mat of vegetal material serves as a valuable mulch besides adding to the organic matter content of the soil. This is an ideal method which avoids disturbance of the shallow topsoil, or the richest part of the soil. Deep ploughing is a mistake generally and on most soils the principal advantage of tillage operations seems to lie in weed control after planting.

SPACING SYSTEMS

The spacing of sisal is a controversial subject. There is no unanimity among sisal growers and the number of different spacing systems which have been tried are legion. Sisal may be planted either in single rows or double rows and each method has its advocates. Trials at Mlingano and elsewhere have shown that the distances between the rows and the plants in the row do not matter a great deal in so far as fibre yields are concerned (LOCK, 1954). An all-important factor is the population of plants per acre. Fibre yields are positively and highly correlated with plant populations up to 4000 plants per acre if the land is rich and the rainfall adequate (LOCK, 1946). Practical considerations impose a limit before this point is reached, in fact half this density, or 2000–2500 plants per acre, has been found most satisfactory from many points of view.

It is essential that workers should have enough room to work without injury to themselves or the plants but the tip thorns on sisal leaves will debar entry into a sisal field if the rows are too close. The importance of

access at all times (other than immediately after cutting) for the control of pests and diseases, obnoxious weeds or bush growth, cannot be over-stressed and accordingly the double-row method of spacing, which provides

Figure 1. View of a field of young sisal in the Tanga district

Figure 2. View of fibre drying lines, with decorticating factory in the background, on a sisal estate in Tanganyika

a wide lane every other row, is becoming common on estates. Furthermore mechanization of inter-row cultivation or weed slashing is easier although the ideal implement has not yet been designed.

CULTIVATION METHODS

Sisal must be weeded frequently when it is young otherwise its growth is retarded and yields are reduced through many of the earliest leaves withering.

Hand weeding of the rows is the rule. This work is difficult to mechanize owing to the plant's squat habit of growth coupled with the rigidity of its leaves and the brittleness of the central spike which can be snapped off easily at its base. Elephants, monkeys and wild pigs may give young fields a setback by breaking off the hearts of plants in this fashion.

Once sisal has reached the cutting stage, one or two weedings per year, plus desuckering, usually suffice for weed control. Large sisal is not greatly affected by a low weed cover but as agaves are intolerant of shade it may be necessary to cutlass tall grasses, bush and climbing shrubs periodically.

When sisal is planted in double-rows spaced 12 feet or more apart it is possible to grow bands of leguminous cover crops, or procumbent grasses such as *Panicum trichocladum* which are not objectionable in any way, between the sisal rows without it offering serious competition. This form of strip cropping affords protection to the soil against erosion and surface capping during heavy rains. In addition the soil is kept cool and the vegetaton provides organic matter as well as material for mulching.

Couch grass (*Digitaria scalarum*) is troublesome in sisal on volcanic soils and experimental work with herbicides is in progress. *Imperata cylindrica* is another difficult weed in some localities. Grasses are generally the dominant species in sisal fields.

HARVESTING LEAVES

Cutting sisal leaves is essentially manual work and it is mainly for this reason that the sisal industry provides plenty of employment. In Tanganyika a cutter cuts, bundles and carries out to a feeder rail-line 2100 leaves, or 70 bundles of 30 leaves each. There appears to be little prospect of mechanizing the actual cutting operation since it requires selective judgement and the tip thorns also have to be snipped off. Mechanization of leaf collection and carrying, however, would be advantageous because each cutter could then undertake a bigger task if he were relieved of these duties, and his work would be less arduous.

The number of cutter's tasks per ton of fibre may vary from 25 for long leaves having a high fibre percentage to two or three times this number for shorter and lighter leaves with a low fibre content. As the output of a decorticator is about 5 tons of dry fibre per day it will be seen that a daily labour force of 120 to 300 men may be required for cutting work alone, the precise number depending upon the quality of the leaves.

As mentioned earlier it is the usual practice to cut sisal fields once a year in localities having an annual rainfall over 35 inches. The unfurling rate of new leaves in influenced most of all by the distribution of the rains. Although sisal is xerophytic, which makes it one of the least speculative crops to grow from the aspect of climate, it grows fastest and generally yields best under a well distributed and fairly high rainfall. When a long and severe drought occurs sisal will cease to grow and its leaves may even wilt badly but it will recover with amazing rapidity as soon as there is rain. Obviously under these conditions the number of leaves grown in a year is reduced and the cutting cycle may have to be extended to 16 months or longer.

Sisal should never be overcut since the removal of too many leaves at any one time seriously stunts the plant. The excessive loss of leaf area as a

result of overcutting has its repercussions because the development of succeeding leaves within the growing spike is affected adversely and subsequently fibre yields decline. These leaves become lighter, shorter and contain less fibre. Cutting costs, of course, rise with the poorer quality of leaf. In practice at least 20–25 leaves should be left on each plant every time it is cut but frequently much vigilance is required to make sure that this standard is adhered to by cutting labourers.

Under favourable conditions, sisal is large enough for its first cutting two or three years after transplanting or when it has grown about 100 leaves. At this stage the plants must not be cut drastically otherwise they never recover and future yields may be halved (Lock, 1955). On the other hand if the first cutting is taken too late and the flower primordia have already been formed, the plants will pole prematurely with loss of crop. The leaves also become too fleshy and this reduces the fibre percentage.

Thousands of records of individual plants made in East Africa have shown that the total number of leaves produced by sisal between transplanting to the field and flowering is more or less limited since it only varies from 200–230 per plant however long the sisal may last. Poor nutrition may lead to a slightly lower leaf potential; frequent and heavy cutting will increase leaf number and concurrently defer poling but without resulting in a higher yield of fibre owing to stunting effects (Lock, 1955).

YIELDS

Table 1 shows yield data from an experiment which are typical of a good field in the best sisal-growing district of Tanganyika. The data show that while the number of leaves obtained annually changes little after the first cutting, the yield of fibre rises steadily as the plants reach maturity or the poling stage. 30 per cent of the plants had started to pole about the time of the fourth cutting and were cut out, hence the peak in yields. These data refer to a plant population of 2000 per acre growing on a red earth under an annual rainfall varying from 45 to 50 inches.

Table 1. Yield data

Cutting	*Mean number of leaves cut per plant*	*Mean weight of fibre per leaf g*	*Fibre yield ton/acre*	*Fibre %*
First	42	9·0	0·76	2·24
Second	27	17·3	0·95	2·78
Third	27	27·2	1·49	4·80
Fourth	28	30·8	1·76	5·48
Fifth	26	26·1	1·36	5·63
Sixth	9	20·9	0·37	4·19
Total	159		6·69	

The life-cycle of sisal is governed by several factors such as soil fertility, rainfall, plant density and cutting methods. In the main producing areas near Tanga, in Tanganyika, sisal fields last for seven to eight years before heavy poling occurs. This means that roughly one eighth of an estate

goes out of production each year which has to be replaced by an equivalent area of 2–3 years old sisal coming into bearing if the annual output of fibre is to be maintained. Under a balanced system of rotational planting, one eighth of the estate, or say, 300–400 acres, should be replanted each year. Theoretically one quarter to one third of the total area should consist of young sisal and two thirds to three quarters should comprise bearing sisal. In addition land may be fallowed for one or two years between cycles. Regeneration of old fields by means of sucker growth selection can be resorted to sometimes in order to avoid too great a fall in production, should a large area of sisal happen to pole out in any year.

MANURING

Sisal is grown on such a vast scale that it is not easy to adopt intensive methods except for bulbil nurseries which may be a matter of only 50 acres or less. Up to the present estates have been dependent upon reserves of soil fertility in either old or new land for their productivity. Some of the best sisal soils are red earths overlying coral rock and many of these have been carrying sisal continuously for over fifty years, and sisal still grows satisfactorily on them except that it may suffer from a deficiency of potassium. Red earths derived from gneiss will carry about two cycles of sisal before yields show a marked decline and manuring becomes necessary. Loose red or pale brown sandy soils are generally exhausted to a large extent after one cycle of sisal.

Agaves are calciphilous plants and under present practice whereby huge tonnages of leaf are removed from the land the soil soon becomes depleted of calcium as well as other nutrients. Sisal growing on acid soils may develop various leaf symptoms which have been given descriptive names such as purple leaf tip roll, tip wither, or chlorotic mottling. These deficiency diseases together with others are being investigated at the Sisal Research Station at Mlingano near Tanga.

The biggest problem facing the sisal industry today lies in finding ways and means of maintaining soil fertility at a reasonable cost. It has been shown (DEN DOOP, 1938) that returning the waste to the land goes far towards compensating for the loss of plant nutrients but this is a herculean task as well as being physically difficult and costly, and a satisfactory solution has still to be found.

Sisal manurial experiments (LOCK, 1954 and 1955) are showing responses to a combination of liming, nitrogenous fertilizers and moderate dressings of sisal waste but the economics of manuring sisal have not yet been fully determined. Sulphate of ammonia is not recommended on soils already lacking in calcium owing to its acidifying effect. Nitrogen has a considerable effect upon hastening growth and improving the colour of the crop especially in semi-arid localities where growth tends to be very seasonal. Sisal is not a heavy phosphate feeder.

Potassium-deficiency symptoms in sisal take the form of bands of necrotic lesions in the basal half of the leaf, known in East Africa as 'banding disease'. Banding disease has been recorded over a wide range of soil types. It is easily corrected by applications of muriate of potash and in one experiment on potassium-deficient land the response in fibre yields was

more than 60 per cent, and highly economic (LOCK, 1954). The use of potassic fertilizers has now become a matter of routine on estates where it is necessary.

Certain disorders of sisal leaves are believed to be due to micronutrient deficiencies or else heavy-metal toxicities. These are being given close study at the moment by the scientific staff at Mlingano.

PESTS AND DISEASES

Fortunately sisal does not suffer from many pests and diseases in East Africa. The Mexican sisal weevil (*Scyphophorus acupunctatus* Gyll.) is virtually the only insect pest. The adults feed upon the epidermis, thus exposing and damaging the peripheral fibres, but the voracious larvae can decimate new plantings by feeding upon the boles of transplants and destroying them. Plant protection measures, using dieldrin or aldrin, have been successful and are well worth while in areas where the sisal weevil is present in large numbers.

Bole rot of sisal was found to be attributable to the fungus *Aspergillus niger* van Teigh gaining entry into the plant through a wound such as a cut leaf base or mechanical damage to the base of the plant during weeding (WALLACE and DIEKMAHNS, 1952). Infection is quite unpredictable but it is often worst during wet weather. Luckily the incidence of bole rot is not great enough to be alarming since control measures would not be simple.

During the small rains season when the weather is hot and showery, sisal is liable to suffer from a condition termed ' sun-scorch '. The epidermal cells burst and the tissue collapses on to the peripheral fibres giving rise to large irregular, sunken patches in the distal half of the leaf. These shrivel up and turn brown and leaves affected in this way cannot be decorticated cleanly. Sun-scorch is not a disease but it is definitely attributable to the state of the atmosphere and it is associated with high humidities coupled with high temperatures. It is most unlikely that a means of control will be found for this reason.

PLANT BREEDING

Agave sisalana is a wild plant originating from the New World. As mentioned before its leaf potential is about 220 per plant and this characteristic automatically restricts the yielding capacity of the plant.

The breeding of new forms of agaves having higher leaf potentials was begun at Amani in 1931 and has been followed up at Mlingano since 1937. This work is very slow owing to the long intervals, often ten years or more, between flowering. A hardy plant producing numerous leaves of the right conformation, free of spiny margins and containing fibre with the right qualities, would go far towards increasing yields per acre. The size of estates could then be reduced and more intensive methods of cultivation could be used. This would help to put sisal production on a sounder agricultural basis.

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Farm Mechanization in Iraq

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Judged on the basis of official statistics, Iraq seems to be sparsely populated. About 5·5 million people are living in an area of 168,400 square miles. But it must not be overlooked that only 15 per cent (25,200 square miles) of the land is under cultivation. Hence, there is a big difference whether the area per head is related to the total or to the cultivated land. Related to the total, only 30 people share in one square mile, but related to the cultivated land the number is 220. Owing to the facts that, on the one hand, population is growing fast, reducing the cultivated area per head, and on the other hand, the standard of living is extremely low, increased agricultural production is vital. Higher productivity can be achieved by the application of improved methods and techniques and/or by land reclamation. In both cases the change-over from human and animal power to mechanical power farming is one of the most important measures. Although all but a relatively narrow belt in the north and northeast of the country has insufficient rainfall to sustain agriculture, the rivers Euphrates and Tigris can provide large amounts of water for irrigation. Much of the soil is inherently fertile and with ample water and mechanical power farming the area under cultivation might be almost tripled.

The main crops at present cultivated in Iraq are dates (of which Iraq is the world's largest producer), wheat, barley and rice. Cotton, citrus fruit, tobacco, potatoes, sugar-beet, sugar-cane and some other crops are only of local importance. In normal years with sufficient rain in the 'rainfall zone' the yields of the main crops even cover the consumption, but they are too low to provide a reasonable food supply. Bad harvests occur relatively frequently and must be compensated by grain imports in order to prevent famine. Livestock, mainly sheep, are almost exclusively kept in deserts and steppes, where the Bedouins struggle for poor pastures and scanty water.

The farming methods have hardly changed for more than a thousand years. An animal-drawn wooden plough, a wooden roller for threshing and some hand tools are all the implements used in farming. Agricultural work that is accomplished in this way obviously demands a large amount of human labour and it is doubtful whether low-priced cereal crops could be grown by this method if wage rates were not so near subsistence level. The techniques of land cultivation show no principal differences between the rainfall zone and the irrigation zone. In the irrigation area, however, some additional work has to be done making border checks, furrows and cross dykes. In consideration of the backward farming system that is still current in Iraq and all over the Middle East, the introduction of farm mechanization appears to offer great advantages in regard to higher agricultural productivity. The change-over from the old-fashioned to the

Figure 1. A traditional and a modern mouldboard plough

Figure 2. Threshing with the ancient wooden roller

Figure 3. Sickle or combine: that is the alternative

Figure 4. Working on irrigation channels with heavy equipment

modern system, however, may cause some serious problems. The most important problems—which also concern other underdeveloped countries of the subtropical area—are the subject of this article.

THE ECONOMIC PROBLEMS

In view of the low standard of living that prevails in Iraq, foodstuffs must be low in price. Nevertheless agriculture does not put landlords in debt under the prevailing conditions. They have divided their huge lands into small pieces which have been allotted to numerous tenants. These tenants pay their farm rent by delivering half of their crops to the landlord. In this way landlords earn an easy income and make their profits in any case: good harvests sell well by quantity, bad harvests by high prices. It is obvious that there is no need and no interest in the view of the landlords to raise production and productivity—at least to raise them by means of capital investments. Actually the landowners are not interested in farm mechanization at all. With each tractor, thresher, or combine they would have to finance, they would share in the production costs and this would result in reduced profit rates. On the other hand the poor tenants and fellaheen are absolutely unable to buy farm machinery at their own expense. The few acres they have under cultivation just keep them alive but do not allow them to improve farming methods by any kind of capital investment. The present economic conditions in Iraq actually offer little inducement in the way of farm mechanization towards improved production. The low prices of the main cereals prevent even modest investments in agriculture, due to the fact that they would eat away the margins of profit. Under the prevailing circumstances a quantitative rise in agricultural production is only possible by extension of land where the same old-fashioned methods can be applied, and human labour can be paid as little as at present.

In the longer run, however, things will probably change completely. The approach to industrial development in Iraq, partly in oil, partly in textile and other branches, is already causing numerous peasants to leave the countryside, searching for employment in industrial plants. Although their wages are still low and their standards of living still remain near subsistence level, people prefer these new jobs. The growth of the population in future will not add to the number of peasants but to the steadily increasing number of industrial workers, and this means less production of food with simultaneously increasing consumption. Without entering into further social problems, it must be stated that this development leads to a dangerous instability in social and economic life and should certainly be prevented. One of the most important measures against this contingency is the improvement of agricultural production in order to correspond to the rising consumption. Approaching this aim, new lines and modern means must be adopted, particularly in farming methods. If the socially bound prices of agricultural products frustrate capital investment based on private initiative, the government should help farmers by granting appropriate subventions and/or cheap long-term credits. These facilities should be granted at least during the first period of the economic and technical evolution until sufficient stability has been achieved. Speaking of Iraq, it seems not to be very difficult for the government to render the

necessary assistance. Actually most of the oil royalties are distributed for purposes of land development.

THE TECHNICAL PROBLEMS

The mode of farm mechanization depends on the principal facts of climatic conditions, soil conditions, the system of cultivation and the sizes of the holdings. All these conditions are related to the various agricultural operations: soil preparation, seeding, planting, harvesting, threshing, transport, etc.

The subtropical climate in Iraq is marked by very hot summer temperatures up to 50°C with simultaneously low humidity of the air down to 5 per cent. Winter temperatures are moderate and some rainfall occurs from December to March. In contrast to tropical conditions, there is not much corrosion attributable to the climate. This is true in particular regarding painted iron and alloyed steel etc. Wooden machine parts become extremely dry, also those made of textile (canvas), leather and the like. These materials may lose some of their elasticity and proper fitting. The life of batteries for tractors, lorries or cars is generally shorter than in moderate climatic zones. Great enemies of all farm machinery, in particular the more complicated kinds, are the various and frequent sand and dust storms coming from the deserts. The dust consists of extremely fine particles which penetrate into nearly everything, causing heavy wear, e.g. in ball- and journal-bearings, gear boxes, cylinders and pistons, in brief at all sliding and rotating surfaces. Oil, grease, and even fuel are usually already infiltrated by dust particles while kept in stock. The enormous dust development which is necessarily connected with tractor work is another danger to farm machines and equipment. In fact engine overhauls are regularly due before the normal period and also the other movable parts of farm equipment must be replaced after relatively short periods of use. The big repair bills make mechanized farming costly and, of course, they do not add to the advantages of farm mechanization. Furthermore it happens very often that spare parts are not in stock in appropriate quantities and consequently repair work is unduly delayed. To this extent mechanized farming in the present stage is not only costly but often unreliable as well.

Soil cultivation is a big problem in Iraq, particularly in the irrigation zone. After the irrigation period is over, the soil dries out within a short time and becomes as hard as brick. The fields are honeycombed with broad and deep cracks. Ploughing is therefore extremely hard work which can hardly be accomplished by the animal-drawn ploughs of the fellaheen even if the land has been irrigated shortly before the job is done. A tractor-type three-furrow mouldboard plough needs 40–50 h.p. if trailed and 35–45 h.p. if mounted. This demonstrates the range of power necessary for primary tillage jobs, but it does not prove the usefulness of the mouldboard plough itself. On the contrary, all trials which have been carried out in the past lead to the conclusion that mouldboard ploughs do not meet the problem. Operation with mouldboard ploughs increases the danger of soil destruction and erosion in the rainfall areas of the north and has the undesirable feature of leaving dead furrows which create a need for additional smoothing operations in the irrigated fields of the south and in central

Iraq. Based on this experience, further trials were made to develop suitable ploughing equipment. Following the principles of the ancient ploughs, a modern type has been constructed that can be defined as a cultivator plough which kills the weeds and tills the soil without turning it. Although these trials are not yet completed, it can be stated that the new type is far more effective than the traditional plough in respect of its performance by acreage as well as in respect of the quality of the job (particularly weed-killing). Furthermore the new design is superior to the ploughs usually in trade in Iraq (mouldboard ploughs) in respect of a considerate treatment of the soil. Disc ploughs are of more use than mouldboard ploughs but do not achieve the capability of the new design. Best success was obtained with the new cultivator plough in conjunction with deep tillage equipment in heavy soil with high compaction of the subsoil.

At the present stage practically no seed drills are used in Iraq. Judging by some investigations we have made, the introduction of this implement would be a great advantage not only by saving seed and producing better germination but also by giving opportunity for better weed control by hoeing, spraying, and cultivation. The advantages of row crop cultivation justify a more intensive use of seed drills in the future. Due to the prevailing conditions, seed drills with furrow openers are to be preferred to ensure good penetration in the cloddy soils.

Fields have to be kept in rather rough condition in both the rainfall and the irrigation zones; in the former due to the damaging effects of heavy rain which occurs in winter and spring, in the latter due to deterioration caused by overflowing irrigation water. Heavy rain and irrigation cause pulverized soils to crust, and the crust cracks when the soil begins to dry. In this case the germination of the seed and the penetration of the young and tender roots through the crust into the moist layer are endangered. The crusted soil can be successfully broken by means of cultivators and harrows if row crop cultivation is applied. Comparative trials with different types of cultivators and harrows have shown that the soil must not be crumbled too finely in order to give it the property to withstand further incrustation. For this reason cultivator springs with duck-foot points are superior to spike and spring-tooth types and disc harrows. At all events the use of cultivators must be undertaken very carefully.

The surface of the land generally allows unlimited operation of all kinds of farm implements, at least if smaller types are used. The operation of large equipment, such as reapers, binders and bulky combines may happen to be difficult in the hilly area of the north, and also in the irrigation area which is criss-crossed by canals and ditches. While this obstruction is inevitable in the mountains, it can and must be removed to some extent in the irrigation zone. A proper layout of the irrigated land is an essential pre-condition to the introduction of the various farm implements and equipment. Nearly all the land devoted to irrigated crops needs some treatment, and much of it will require considerable earth-moving to prepare it. If this is accomplished, graded land will permit full utilization of the machines and also better control and more economical use of the irrigation water. Nevertheless, the irrigated land must necessarily be interlaced by canals and ditches and therefore reapers, binders and self-propelled

combines are superior to large and unwieldy tractor-drawn combines. The harvesting machines should cut the crop as low as possible in order to harvest most of the straw, which is a very important animal forage in Iraq. In areas where combines cannot be operated effectively due to the topography of the land, binders may be used with good results. Even reapers accelerate the harvest and make the job easier if compared with the sickle which is generally used in Iraq at present. Scythe and cradle are practically unknown in this country. Although reapers do not save any time or work in further treatment after the cutting operation, this equipment should be used preferably where no tractors are available or where the topography of the land makes the operation of binders and combines impossible. In small holdings even the scythe and cradle would be an important advance, because five times more green forage crops can be harvested with a scythe and three times more grain with a cradle than with a sickle.

The threshing method by means of the old-fashioned rollers is very ineffective. Nevertheless the threshing costs are about 3 or 4 per cent of the value if animals must be hired to accomplish the process by trampling. Winnowing the grain with wooden forks and shovels is as fussy as the threshing process. Therefore the introduction of power threshers would be a considerable advantage to all those farmers who do not have a combine. In view of the fact that forage crop cultivation is rather difficult in Iraq, bruising of straw is very important, but straw bruising always needs a power equipment. With this in mind the introduction of small pedal-operated threshers does not appear very useful. Moreover mechanized grain cleaning, which is combined with the threshing process in a modern power thresher, will add to better weed control.

The greatest amount of labour in Iraq's agriculture at the present stage is devoted to the transport of crops from the fields to the villages. Usually all loads are taken from the fields to the villages on the backs of animals (donkeys) and frequently on the backs of men and women. It may be confessed that this is still an appropriate method due to the bad condition of roads and paths. But in the longer run wheeled carts and rubber-tired farm wagons would be more economical. Transportation on the backs of men and animals is not cheap at all if, due to the excessive loads, the animals are liable to drop dead—and this occurs more than a few times.

Having regard to the limited kinds of crops which can be successfully cultivated in Iraq, the selection of farm machinery does not appear very difficult. In both the rainfall and irrigation zones wheat and barley are the dominant crops. The methods of primary and secondary tillage depend less on the crops than on the condition of the soil. The special requirements have been mentioned above. Some special crops, e.g. cotton, rice, sugar-beet, forage crops etc., need special equipment for secondary tillage, planting and harvesting if those crops should be extended to an amount where mechanization appears to be necessary and useful. With further development in agriculture, manure and fertilizer distributors and sprayers for weed control will be needed to complete the assortment. None of these machines needs special attachments or modifications in respect of the agricultural conditions prevailing in Iraq.

The selection of farm machines in relation to the various sizes of the

holdings should be thoroughly planned in correspondence with the experiments which farm machinery experts have made in the past. The small farms in the north and in the settlement projects which have been recently established by the government should start with a selection of animal-drawn implements of modern type which are far superior to the ancient tools still in use. Larger and more costly equipment can be successfully maintained by agricultural machinery cooperatives.

TRAINING OF OPERATORS AND MAINTENANCE OF MACHINES

Successful use of farm machines depends greatly on the thorough training, carefulness and experience of the operators and on proper treatment and maintenance of the machines. In a previous section it has been mentioned that the enormous development of dust does much harm to all sliding and rotating parts of any farm machine. Neglect of servicing and maintenance would quickly lead to ruin. Trained mechanics and operators are therefore key men of successful farm machinery development. At the present time there are not enough trained people and tools, and shop space, transport equipment and other needed facilities are not generally adequate to care for the existing machinery. As machinery becomes badly worn it seems to be the policy to cast it aside and call for complete replacement. The common reason given for this attitude is that spare parts are not available, hence the equipment must be abandoned. But actually most of the idle equipment observed in the country still has several years of useful life remaining if it were to be kept in reasonable repair. To meet both aspects of the problem, the government recently established operators' courses and maintains several government-owned workshops where people are trained in all branches necessary for their intended jobs. Recently some dealers started a training programme for their staffs and it can be expected that in due time a corps of skilled mechanics and operators will be built up and this is most important because throughout the country the need for trained mechanics and maintenance facilities is very acute.

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The Fibres of Australimusa *in Relation to Abacá Improvement*

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Australimusa is a section of the genus *Musa* in which is placed *Musa textilis* Née, Abacá or Manila hemp, the world's foremost cordage fibre, valued particularly for marine work because of its great strength and resistance to the corrosive action of salt water. A useful review of the crop is given by Spencer (1953).

The main area of production of Manila hemp is the Philippines which still maintain a virtual monopoly, successful cultivation of the crop in Central America, Sumatra and North Borneo notwithstanding. Previous attempts to introduce Abacá to other tropical areas have proved unsuccessful. This is probably a result of the exacting soil and climatic requirements of the species and the high cost of production of the fibre, particularly where labour is not skilled in handling the crop.

Abacá breeding has previously been confined to the Philippines. It has consisted mainly of hybridization between varieties. A recent study connected with Abacá breeding is that of Umali and Valdez (1951) in which the crossing relationships of Pacol and Canton with Abacá were studied. It was hoped that hybrids might be produced which would have the immunity to mosaic of Pacol and Canton while still retaining the desirable fibre qualities of Abacá. Results showed that Abacá and Pacol could be hybridized while the crosses Abacá × Canton and Pacol × Canton failed. These results are not surprising in view of the fact that Pacol is *M. balbisiana* Colla (section *Eumusa*, 2n=22) while Canton is a male- and female-sterile hybrid (2n=21) between Pacol and Abacá (*M. textilis*—section *Australimusa*, 2n=20) (Cheesman, 1949). It seems unlikely that Pacol and Canton will prove useful in an Abacá improvement programme. In fact, the only alternative (or adjunct) to intra-*textilis* (*i.e.* varietal) crosses is the use of other Australimusas in a hybridization programme with Abacá. This has now been realized in the Philippines and at least one *Australimusa*, *M. lolodensis* Cheesman, is being used in a programme of hybridization with a view to obtaining mosaic-resistant plants. The stock* of this species used has been found to be highly resistant to mosaic (Kent, 1954).

Among the banana collections at the Imperial College of Tropical Agriculture are a number of Australimusas and hybrids between them. Their fibre characteristics are described in this paper, the investigation having been planned as a preliminary to the use of interspecific hybridization in

* Presumably directly descended from the type clone of the species (*I.R. 247*, see below), of which seed was sent from the Imperial College of Tropical Agriculture to the Philippines in 1951 for this specific purpose.

Abacá improvement. The work to be described was carried out at the Regional Research Centre of the Imperial College of Tropical Agriculture during the tenure of a scholarship from the Administration of New Guinea and Papua; it has been submitted in part fulfilment of the requirements for the Diploma in Tropical Agriculture (D.T.A.) of the College.

MATERIALS AND METHODS

The tensile strength and thickness of their fibres have been determined for the following *Australimusa* species and interspecific hybrids. All are diploid with 2n=20, except as otherwise indicated. I.R. numbers refer to the I.C.T.A. Introductions Register, S.H. numbers to the Species Hybrid collection.

M. textilis Née (Cultivated clones: Tangongon, I.R. 240; Libuton, I.R. 239; St Vincent, I.R. 71).
M. lolodensis Cheesman (I.R. 247, the type clone from Halmaheira, Indonesia).
M. peekelii Lauterbach (I.R. 229, from New Ireland).
M. maclayi F. v. Mueller (I.R. 200 and 201, from Buka, Solomon Islands, type clones of *M. erecta* Simmonds).
M. angustigemma Simmonds (I.R. 194 and 395, from New Guinea, the former the type clone).
M. lolodensis × *M. textilis* (S.H. 136, a triploid, LLT).
M. textilis × *M. lolodensis* (S.H. 142).
M. lolodensis × *M. peekelii* (S.H. 141).
M. peekelii × *M. lolodensis* (S.H. 117).
M. peekelii × *M. angustigemma* (S.H. 146).
M. textilis × *M. peekelii* (S.H. 144).
M. textilis × *M. angustigemma* (S.H. 148).

Similar examinations have been made of *M. violascens* Ridley (I.R. 108, from Malaya—section *Callimusa*, 2n=20) and of the Eumusas: *M. balbisiana* Colla (several clones of various origins), *M. basjoo* Sieb. (I.R. 78A, from Ryukyu Archipelago, Southern Japan), *M. itinerans* Cheesman (I.R. 185, the type clone, from Northern Burma) and of four hybrids between *M. violascens* and some Australimusas (*M. violascens* × *textilis*, S.H. 27; *M. textilis* × *violascens*, S.H. 143; *M. lolodensis* × *violascens*, S.H. 135; and *M. violascens* × *M. lolodensis*, S.H. 114).

Mature pseudostems were harvested. Tuxies were prepared from the outer edges of each leaf sheaf. Well-cleaned fibres were obtained by removing the excess pulpy material from the tuxies in a hand hagutan (*Figure 1*). A metal knife was attached to a 3×2 inch wooden cross-arm pivoted at its central point on a 4×4 inch wooden upright. A weight (in this case a bucket of sand) on the opposite end of the cross-arm forced the knife against a smooth and rigidly fixed wooden block. A treadle, attached by a wire to the cross-arm, allowed the knife to be drawn away from the wooden block to facilitate the insertion of the tuxies (*Figure 2*). When the treadle was released the tuxies became clamped between the knife and the wooden block. Sufficient force was exerted by the weight to allow the pulpy material to be removed from the tuxies when pulled evenly over the knife (*Figure 3*).

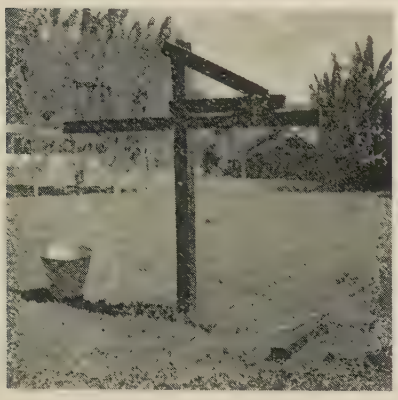

Figure 1. The hagutan used for extraction of Musa *fibres*

Figure 2. The treadle of the hagutan is depressed to allow the tuxy to be inserted

Figure 3. The treadle is released and the tuxy is cleaned of pulpy material when pulled between the metal knife and wooden block

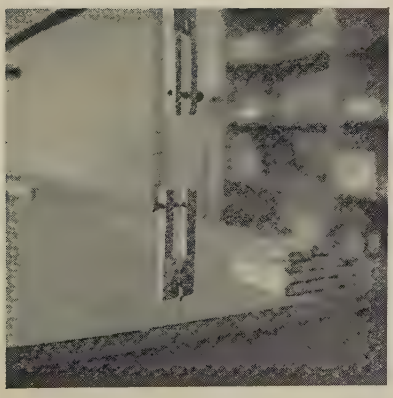

Figure 4. A mounted fibre ready for breaking

Figure 5. The steel girder supported at its central point

The fibre from each species was sun-dried and then sampled until sufficient material was obtained for testing. Only the middle section, 25 cm long, was used. From each sample 25 fibres were selected so that they constituted a size range from the finest to the coarsest. Single fibres were mounted on specially made wooden mounts with the aid of cold-water glue which was allowed to harden overnight. Wooden pegs 5 mm in diameter were inserted through holes in each mount and a turn of the fibre was taken around each peg (*Figure 4*).

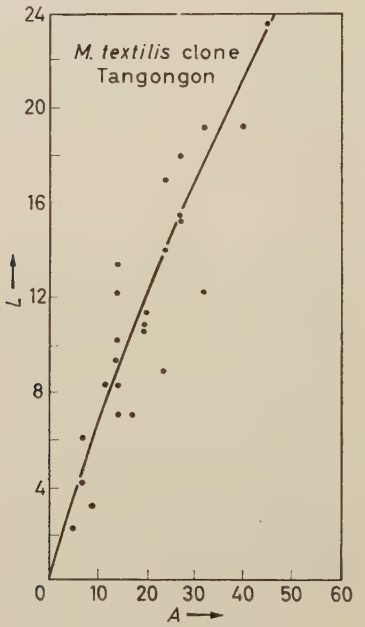

Figure 6. Breaking load/cross-sectional area scatter diagram of M. textilis *clone Tangongon*

One mount was attached to a cup-hook screwed into the bench, the other to a cup-hook attached to the end of a steelyard. The steelyard was made from an L-section steel girder 210 cm long. The girder was graduated in decimetres and nicks were cut at suitable intervals so that it might be placed accurately upon a knife-edge as fulcrum. The knife-edge was supported, at a height of 30 cm above the bench by clamps attached to two retort stands (*Figure 5*).

The apparatus allowed for adjustment of the fibre–fulcrum distance. Tension on the fibre was obtained by moving a kilogramme weight in a distal direction along the steelyard. Weaker fibres were broken with the girder supported at its central point. For stronger fibres the girder was supported at a fibre–fulcrum distance of 80 or 60 cm. Graphs of distances and breaking strengths were constructed from a knowledge of the weight and length of the girder. When the fibre snapped the distance from the fulcrum of the kilogramme weight was noted and the breaking load

was read directly from the appropriate graph. The diameter of each broken fibre was measured on a binocular microscope and the cross-sectional area computed. Most of the fibres measured were circular in cross-section but the remainder showed varying degrees of flattening. The approximate cross-sectional areas of such fibres were calculated from the means of the measurements of long and short diameters.

The mean fibre-thickness of each species and hybrid was determined by measuring the diameters of a sample of 100 fibres.

RESULTS

The relationship between the size and strength of fibres was determined by constructing a graph for each clone studied. The breaking load L (units of 100 g) of each fibre was plotted against its cross-sectional area A (units of 10^{-3} mm^2). The scatter diagram for *M. textilis* clone Tangongon is shown in *Figure 6*; the other plants studied all gave similar scatters. *Figures 7* to *11* illustrate the relationships between L and A in Australimusas and their hybrids. *Figure 12* shows the graphs for some miscellaneous species, *Figures 13* and *14* for *M. violascens* and its hybrids.

Table 1. Pseudostem length and diameter and strength of fibres of Australimusas and hybrids

Species or hybrid	*Pseudo-stem length*	*Mean diam. of fibre*	*Mean breaking load of fibre*	*Tensile strength of fibre*	*Upper limits of:*	
					Diameter	*Breaking load*
	dm	*mm*	*g*	*kg/mm²*	*mm*	*g*
M. textilis clone St Vincent	18	0·135	1000	69·9	0·185	1670
M. textilis clone Tangongon	40	0·165	1305	61·0	0·238	2360
M. textilis clone Libuton	34	0·163	1170	56·2	0·386	1980
M. peekelii	49	0·116	540	50·9	0·172	800
M. angustigemma	40	0·127	600	47·4	0·228	1150
M. lolodensis	34	0·143	720	44·8	0·185	1030
M. maclayi	49	0·146	620	37·0	0·211	970
M. textilis (St V.) × *M. peekelii*	34	0·138	850	56·9	0·199	1330
M. peekelii × *M. angustigemma*	37	0·122	660	56·5	0·145	910
M. textilis (Tang.) × *M. angustigemma*	40	0·144	830	51·0	0·236	1410
M. textilis (St V.) × *M. lolodensis*	21	0·148	860	50·0	0·264	1480
M. lolodensis × *M. textilis* (St V.)	37	0·129	620	47·4	0·238	1800
M. peekelii × *M. lolodensis*	40	0·134	620	44·0	0·264	840

Results are summarized in *Tables 1* and *2*. Length of mature pseudostem refers to the distance between its base and the point of emergence of the inflorescence. The breaking load corresponding to the mean cross-sectional area of the fibres is given as the mean breaking load. The tensile strength was computed from the formula

$$\text{Tensile strength (kg/mm}^2) = \frac{\text{mean breaking load (kg)}}{\text{mean cross-sectional area (mm}^2)}$$

The upper limits of breaking load and fibre diameter are also given.

Table 1 shows that the Tangongon and Libuton clones of *M. textilis* have the coarsest fibre and highest mean and maximum breaking loads.

Figures 7 to 14. Curves of L *(breaking load) against* A *(cross-sectional area of fibre) for various* Musa *species and their hybrids*

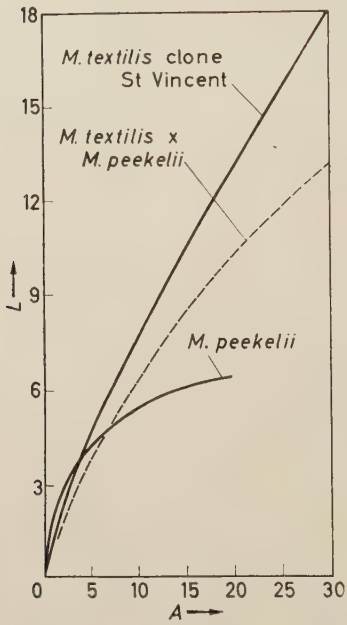

Figure 7. M. textilis (*St V.*), M. peekelii *and* M. textilis × M. peekelii

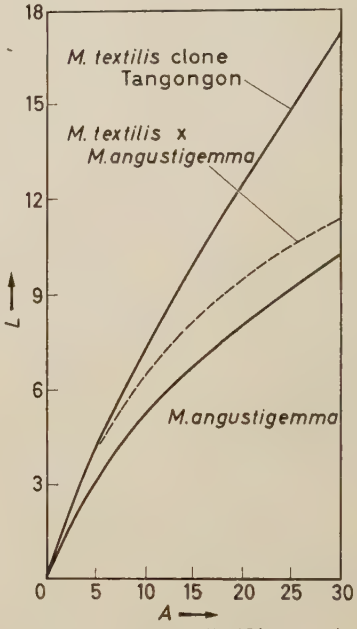

Figure 8. M. textilis (*Tangongon*), M. angustigemma *and* M. textilis × M. angustigemma

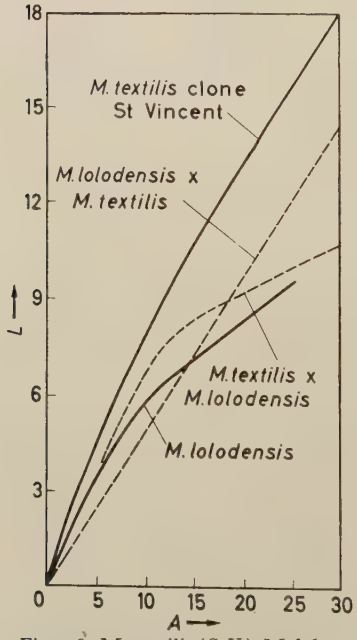

Figure 9. M. textilis (*St V.*), M. lolodensis *and* M. lolodensis × M. textilis *and* M. textilis × M. lolodensis

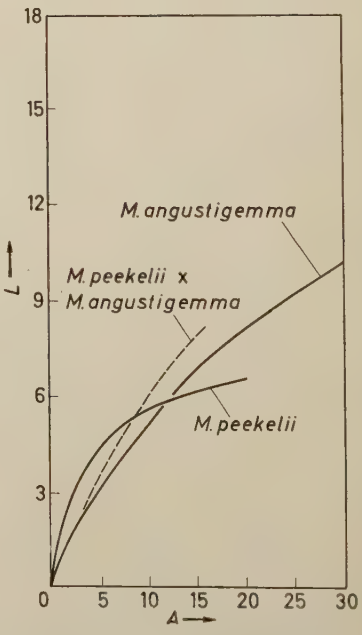

Figure 10. M. angustigemma, M. peekelii *and* M. peekelii × M. angustigemma

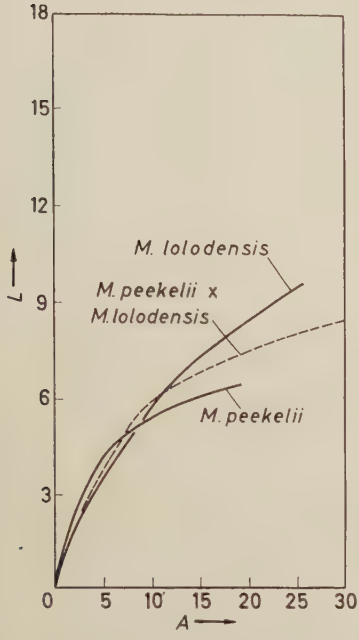

Figure 11. M. lolodensis, M. peekelii *and* M. peekelii × M. lolodensis

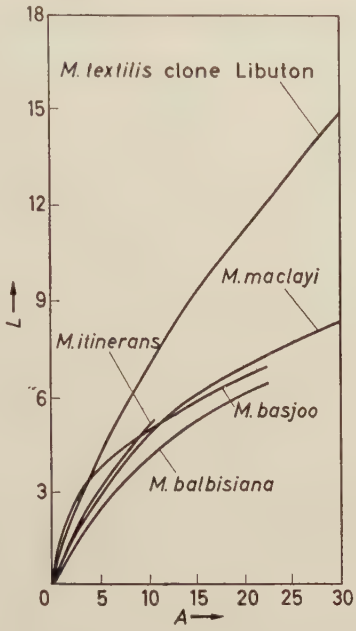

Figure 12. M. textilis (*Libuton*), M. balbisiana, M. basjoo, M. itinerans *and* M. maclayi

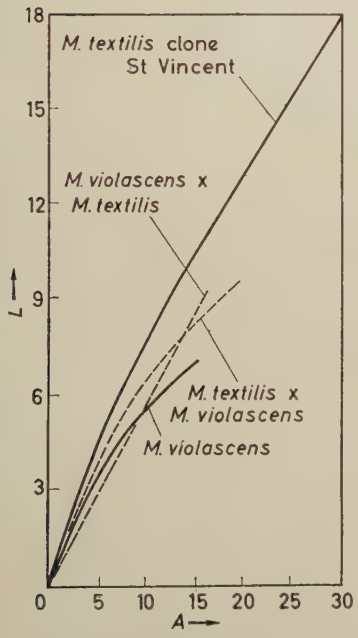

Figure 13. M. textilis (*St V.*), M. violascens *and* M. textilis × M. violascens *and* M. violascens × M. textils

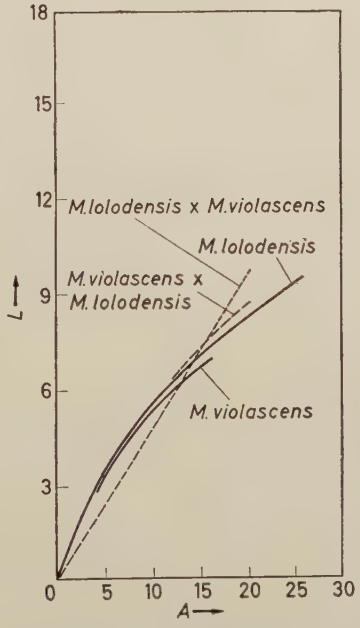

Figure 14. M. lolodensis, M. violascens *and* M. lolodensis × M. violascens *and* M. violascens × M. lolodensis

The St Vincent clone has the highest tensile strength but its fibres are finer than those of the other Abacá clones. Interspecific hybrids which have *M. textilis* as one parent have tensile strengths and fibre diameters not far removed from those of the Tangongon and Libuton clones of Abacá. The fibres of *M. peekelii* × *M. angustigemma* have a high tensile strength but are very fine. *M. lolodensis* × *M. textilis* (which is a triploid of constitution LLT) has fine weak fibres. *M. peekelii* × *M. lolodensis* has weak fibres. The fibres from all species and hybrids have satisfactory colour and sheen.

Table 2 shows that *M. basjoo*, *M. itinerans* and *M. violascens* have strong but very fine fibre. *M. basjoo* is cultivated in southern Japan for its fibre (BAKER, 1893). The most promising hybrids from the point of view of both tensile strength and fibre diameter are *M. textilis* × *M. violascens* and *M. peekelii* × *M. violascens* but neither is a robust plant. In fact none of the hybrids in *Table 2* compares favourably with the best *Australimusa* hybrids in *Table 1*.

Table 2. Pseudostem length and diameter and strength of fibres of some Musa *species and hybrids*

Species or hybrid	*Pseudo-stem length*	*Mean diam. of fibre*	*Mean breaking load of fibre*	*Tensile strength of fibre*	*Upper limits of:*	
					Diameter	*Breaking load*
	dm	*mm*	*g*	*kg/mm²*	*mm*	*g*
M. basjoo (Eumusa)	18	0·092	405	60·9	0·172	670
M. itinerans (Eumusa)	24	0·098	415	55·0	0·118	670
M. balbisiana (Eumusa)	46	0·114	410	40·2	0·172	740
M. violascens (Callimusa)	12	0·108	500	54·6	0·145	860
M. acuminata × *M. textilis* (St V.)	21	0·110	645	67·9	0·158	1350
M. peekelii × *M. violascens*	24	0·118	705	64·4	0·172	1000
M. violascens × *M. textilis* (St V.)	18	0·114	585	57·3	0·146	860
M. textilis (St V.) × *M. violascens*	18	0·136	825	56·8	0·158	1000
M. violascens × *M. lolodensis*	21	0·118	585	53·5	0·158	950
M. lolodensis × *M. violascens*	18	0·112	480	48·7	0·158	1000
M. violascens × *M. angustigemma*	27	0·116	525	49·7	0·158	810

CONCLUSIONS

Although none of the hybrids mentioned in this paper will be ignored in further investigations, the results indicate that the species which will prove most useful in Abacá improvement programmes are *M. peekelii*, *M. angustigemma* and *M. lolodensis*. Although hybrids between these species and *M. textilis* produced weaker and finer fibres than would be acceptable to the cordage trade it is probable that several generations of back-crossing to a vigorous clone of *M. textilis* would give improvement of the fibre sufficient for it to compare favourably with commercial grades of Manila hemp. Polyploid hybrids would also be well worth investigation.

The desirable characteristics of the Australimusas have not yet been completely investigated. It is known, however, that at least one of them, *M. lolodensis*, possesses resistance to Abacá mosaic (KENT, 1954). SIMMONDS (1956) comments upon the apparent drought tolerance of the *M. textilis* × *M. peekelii* hybrid growing at the I.C.T.A., Trinidad. *M. peekelii*, *M. lolodensis* and *M. angustigemma* are vigorous and in this respect are more promising than *M. maclayi* which, although robust, is not vigorous, and the *Callimusa*, *M. violascens*, which is a weakly species.

That a breeding programme involving the use of wild relatives of Abacá is necessary is evidenced by the fact that the recovery of the Philippines Manila hemp production to its pre-1939 level has been severely retarded by disease, particularly by mosaic (JULIANO, 1951). Plantations in North Borneo are suffering from bunchy top infestation (ANON., 1955). Abacá grown in Central America is free from virus but other troublesome diseases (ROBINSON and JOHNSON, 1953) may prove to be controllable by the synthesis of disease-resistant clones.

SUMMARY

The diameter and strength of fibres of five species of *Australimusa*, of hybrids between them and of certain other members of the genus *Musa* have been determined. Results indicate that interspecific crosses of *M. textilis* with *M. peekelii*, *M. angustigemma* and *M. lolodensis* may be of value in Abacá improvement programmes.

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Experiments on the Use of Transplanted Stumps for Establishing Tea in Nyasaland

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Most of Nyasaland's tea estates are actively engaged in planting new areas to tea or in uprooting and replanting areas of unproductive old tea. The resulting stands after planting have been very variable and frequently not good enough to justify the expenditure involved.

Low original stands have disadvantages. Yield per acre with tea is in positive proportion to the numbers of plants per acre within the range of spacings commonly used in commercial practice and consequently potential yield will be lost by an incomplete population (Laycock, 1951). Supplies become increasingly more difficult to establish as the surrounding older tea matures (Anon., 1955–56a). Tea is a plant requiring skilled management methods throughout its life and these, progressively changing according to age, are particularly important during the early formative years. Consequently mixed stands of varying ages make field operations difficult, particularly so when labour forces are largely unskilled.

With this background a series of prototype observations on the establishment of tea was made and by 1952 sufficient experience had been obtained to allow a series of statistically designed experiments to be carried out, which are recorded below.

It is convenient to describe here what tea stumps are and why Nyasaland favours using them in preference to the more popular Far Eastern methods of transplanting rooted seedlings in one form or another. In Nyasaland seed is germinated and planted into nursery beds wherein the seedlings are left for approximately eighteen or thirty months. At the end of either of these periods each suitable seedling is pruned at 4 in. above soil level which leaves a leafless stem. Pruned seedlings are then uprooted and transplanted in the field, no attempt being made to leave soil adhering to the root-systems. The uprooted leafless stem, approximately 4 in. long, together with its bare tap-root is a stump.

Seed harvest begins about February and ends about May; that is during the end of the rains. Under natural conditions tea seed quickly loses viability and seed must be germinated shortly after harvest if best results are to be obtained. Attempts to store large quantities of seed for any length of time have proved costly and not very satisfactory (Leach, 1936). Consequently newly germinated seedlings are produced during the early part of the dry season which becomes progressively more severe, reaching its full intensity during late September, October and mid-November before the break of the next rains (*Figure 3*). It becomes essential therefore to

provide water for seedlings during the dry season and the topography of the Nyasaland tea areas is such that perennial streams are usually found in well defined valleys away from areas suitable for permanent tea.

Herein lie the main reasons for the preference for stump planting. Topographical limitations restrict the land suitable for nursery sites both in position for watering and for actual areas of suitable soil type. These sites are frequently some distance, even miles, away from the permanent fields. Stumps without soil attached are easily and cheaply transported from the nursery to the field. Soil is left *in situ* and after rejuvenation can be re-used, an important factor when nursery areas are limited. Stumps can be easily planted with the unskilled labour forces available to the Nyasaland industry.

Planting of rooted seedlings as favoured in the Far East would increase transport costs and, more important, would rapidly deplete the soil of the limited nursery areas available. Seed at stake has not proved successful because of the onset of the long dry season shortly after germination.

Stumps are transplanted after the break of the main rains and establishment is considered to be complete at the start of the following rains, after which few survivors die.

Perhaps the major step forward in the successful use of stumps was made by Leach in 1935–36 when he demonstrated the remarkable effectiveness of shading the collar of the stump against the intense heat reflected from the soil surface (Anon., 1936). Unshaded stumps were scorched and ring-barked at ground level. A 'collar-pot' has since been developed and consists of a roughly baked hollow cylinder of clay about 4 in. high and 3 in. in diameter, made on the station, usually from an ant-hill in or near to the field.

EXPERIMENTAL METHODS

Each experiment was laid down at two widely separated sites and with minor modifications experiments were replicated at each site for three successive planting seasons; 1952–53, 1953–54 and 1954–55.

The first site was at the Mimosa Tea Research Station in Mlanje district and is typical of the wetter and more congenial conditions of the Nyasaland tea areas. The second site, at the Bvumbwe Tung and Agricultural Experimental Station, is some 40 miles to the west of Mimosa in a much drier area and about five miles west of the nearest commercial Cholo tea. This area was chosen as representing marginal and far more rigorous conditions than pertain in Mlanje, or even in the heart of the Cholo tea belt.

The success, or otherwise, of experimental treatments was gauged by two factors; first the percentages of plants which were alive 12 months after transplanting and secondly the vigour of growth measured by the weight of prunings taken at the first prune in the field at approximately 16 months after planting. The criterion of 'survival', although obviously straightforward, gives only a partial indication of the success of treatments. Surviving bushes at the end of the first 12 months can show great variation in vegetative growth (vigour). At the lower end of the scale the stump may only have produced one or two small shoots with

not more than five leaves each and at the other end a vigorous young bush may have been produced with many shoots each bearing many leaves. A simple survival count does not indicate these differences. Pruning weights were therefore measured to supplement the survival counts.

(a) *1952–53 replications*

(Planted December 1952, survival counts taken December 1953 and pruning weights April 1954.) Five treatments each at two levels were compared in a 'two-to-the-fifth' factorial design with, at each field site, two complete replications each partially confounded in four blocks each of eight plots. One hundred stumps were planted in each plot, plots being square. Square plots, although inefficient in overcoming soil differences (LAYCOCK, 1955), were deliberately chosen so that a minimum edge effect would be felt by unshaded plots adjacent to those shaded with a tall bushy legume cover crop. Long narrow plots would increase inter-plot shade effects at certain times of the year when the sun's declination is low and narrow plots arranged with their length parallel to the sun's declination would increase daily orbital effects.

Treatments compared were:

(*i*) Age of stump from seed: approximately 18 or 30 months.

(*ii*) Nursery fertilizer: stumps grown in the nursery with or without 2 oz. per square yard of nursery bed of a 6:10:8 fertilizer mixture. Ingredients being sulphate of ammonia, superphosphate and muriate of potash.

(*iii*) Shade: either by collar-pots as described above, or by growing *Tephrosia vogelii* between the tea rows. As the *Tephrosia* grew in height it was trimmed to form an 'umbrella' type of shade over the tea by lopping off all branches on the main stem up to a height of 4 ft above ground.

(*iv*) 'Starter' fertilizer: with or without 1 oz. per plant of the 6-10-8 fertilizer mixture placed at planting time in two holes 3 in. on either side of the stump and 1 in. deep.

(*v*) Length of stump: seedlings in the nursery pruned at 4 or 8 inches above soil level before uprooting.

Some amplification of these treatments is necessary. At the start of these experiments there was argument as to the optimum size of stump to be planted and, although no precise information was available, it was generally conceded that 'size' referred to the diameter of the seedling at the pruning cut. Two schools of thought pertained, the first holding to the suitability of the 'size' of an average 18 month old stump and the second to a stump 12 months older. In view of the lack of precise information on survival and stump diameter, both age groups were included and supplementary measurements were made on each experiment. No selection of stumps by diameters was made in the nursery at uprooting time and all live and apparently non-diseased plants, of no matter what diameter, were planted in the field. Immediately after planting, approximate diameter measurements were made on all stumps by fitting to them, at 4 in. above soil level, the nearest semi-circle of a board originally drilled with a series of holes each increasing by 1/16 in. in diameter and then split down the centres of its holes. Each semi-circle was numbered and the number

of the nearest fit was recorded on a field plan showing the exact location of the stump. In the December after planting when survival counts were made, each stump was recorded against its diameter as being dead or alive thereby yielding data of stump diameters and related survival percentages. All stumps were grown in the Mimosa nurseries.

Immediately after planting, the stump offers no shade to itself or to the soil from its own foliage and some five years elapse before a complete canopy is formed over the soil. The beneficial effects of shading the stump at soil surface by collar-pots was amply demonstrated experimentally by Leach and later by field scale usage, but in view of Far Eastern practice a second shade treatment was included—that of growing *Tephrosia vogelii* (an established Nyasaland species) between the tea rows in the hope that it would shade both stump and soil.

Under natural conditions the tea plant grows into a tree. In order to stop this upright growth and to form a low bush suitable for plucking, tea is pruned at regular intervals. Pruning of young tea must be done with special care, the aim being to obtain the maximum of vigour and spread with a minimum of delay. The cutting back of the seedling in the nursery to form a stump amounts to the first prune in the shaping of the new bush and, as such, a comparison was desired between two heights of first prune. This is not strictly a treatment which can be expected to affect survival but it was convenient to include the comparison in the 1952–53 experiments.

(b) *1953–54 and 1954–55 replications*

Main treatments and records taken were exactly as described for 1952–53 except that the length of stump comparison was excluded. Plots were square, each of 100 stumps, and the design for each experiment was a ' two-to-the-fourth ' factorial arrangement with two complete replications, each being partially confounded between four blocks each of four plots.

RESULTS

Percentage deaths according to experimental treatments are recorded in *Tables 1*, *2* and *3*.

Table 1. 1952–53 replications—percentage deaths according to treatments

Site	Age		Nursery fertilizer		Shade		Starter fertilizer		Length of stump		Mean
	18mos.	*30mos.*	—	+	*Pots*	Tephrosia	—	+	*4 in.*	*8 in.*	
Mimosa	13·6	12·0	15·5	10·1	10·8	14·8	14·0	11·6	11·2	14·4	12·8
Bvumbwe	24·7	13·9	19·4	19·4	15·5	23·1	20·8	17·8	21·0	17·6	19·3

LSD Mimosa, at $P=0{\cdot}05, =3{\cdot}2$; at $P=0{\cdot}01, =4{\cdot}3$.
LSD Bvumbwe, at $P=0{\cdot}05, =4{\cdot}2$; at $P=0{\cdot}01, =5{\cdot}7$.

No significant differences resulted from age of stump at Mimosa but at Bvumbwe the older stumps were significantly more efficient.

Nursery fertilizer whilst having no significant effect at Bvumbwe significantly reduced the percentages of death at Mimosa.

For both stations, at $P=0{\cdot}05$, *Tephrosia* significantly increased the percentage deaths over stumps shaded with collar-pots.

Starter fertilizer did not significantly reduce the numbers of deaths at either station.

At neither station did the length of stump significantly affect survival. The taller stump gave rise to new growth too high above soil level for desirable shaping of the young tea bush and was consequently omitted from the remaining replications.

There were no significant interactions between treatments.

Table 2. 1953–54 replications—percentage deaths according to treatments

Site	Age		Nursery fertilizer		Shade		Starter fertilizer		Mean
	18mos.	30mos.	—	+	Pots	Tephrosia	—	+	
Mimosa	36·6	28·6	31·5	33·7	16·1	49·1	30·8	34·4	32·6
Bvumbwe	43·7	40·0	40·0	43·7	30·2	53·5	42·4	41·3	41·9

LSD Mimosa, at $P = 0{\cdot}05$, $= 9{\cdot}0$; at $P = 0{\cdot}01$, $= 12{\cdot}8$.
LSD Bvumbwe, at $P = 0{\cdot}05$, $= 9{\cdot}1$; at $P = 0{\cdot}01$, $= 12{\cdot}9$.

For these replications only the shade treatments caused any significant differences. At both stations *Tephrosia* caused highly significant increases in percentage deaths over stumps shaded with collar-pots.

There were no significant interactions.

Table 3. 1954–55 replications—percentage deaths according to treatments

Site	Age		Nursery fertilizer		Shade		Starter fertilizer		Mean
	18mos.	30mos.	—	+	Pots	Tephrosia	—	+	
Mimosa	7·6	7·0	6·9	7·7	5·2	9·4	7·0	7·6	7·3
Bvumbwe	21·8	13·3	18·6	16·5	13·5	21·6	15·1	20·0	17·6

LSD Mimosa, at $P = 0{\cdot}05$, none.
LSD Bvumbwe, at $P = 0{\cdot}05$, $= 6{\cdot}4$.

At Bvumbwe *Tephrosia* grew extremely badly in spite of being replanted four times with identical seed to that used at Mimosa where this shade flourished. In these circumstances the shade treatments at Bvumbwe virtually became a comparison between the effects of collar-pots and no shade.

At Mimosa no significant differences were caused by treatments. *Tephrosia* as in previous seasons increased the numbers of deaths over collar-pots and this difference, although not significant, is the widest between any sets of treatments.

At Bvumbwe 30-month old stumps were more efficient than the younger stumps and no shade (which should have been *Tephrosia* had it grown) caused significantly more deaths than stumps shaded with collar-pots, confirming thereby Leach's observations made in 1935–36.

There were no significant interactions.

Before recording the pruning weight data, it is perhaps as well to point out that the mean percentages of deaths shown in *Tables 1*, *2* and *3* are higher than those obtained in straightforward planting at Mimosa. This is because of treatment effects and because in these experiments no selection for stump size was made, all living stumps being planted. Under normal conditions on the stations, selection for stump diameter is made, and stands over five years of planting have never been less than 92 per cent successful.

Tables 4, *5*, *6* and *7* record fresh weights of prunings taken at first prune and each treatment pair of entries are expressed as percentages of the total weights of prunings taken.

Mimosa was described above as being a wetter and more congenial area for tea than Bvumbwe where conditions are considered to be marginal. A quantitative expression of these differences is given by the comparison of total pruning weights taken between stations. For the 1952–53 experiments total prunings at Mimosa were 4·6 times as heavy as those at Bvumbwe; the 1953–54 and 1954–55 replications gave factors of 4·3 and 8·2 respectively.

Table 4. 1952–53 pruning weights expressed as percentages of the total yield

Station	Age		Nursery fertilizer		Shade		Starter fertilizer		Length of stump	
	18mos.	*30mos.*	—	+	*Pots*	Tephrosia	—	+	*4 in.*	*8 in.*
Mimosa	42·5	57·5	49·0	51·0	66·7	33·3	37·0	63·0	50·7	49·3
Bvumbwe	28·3	71·7	50·1	49·9	72·8	27·2	39·4	60·6	44·5	55·5

LSD Mimosa; at $P=0{\cdot}05$, $=7{\cdot}7$; at $P=0{\cdot}01$, $=10{\cdot}3$.
LSD Bvumbwe; at $P=0{\cdot}05$, $=11{\cdot}3$: at $P=0{\cdot}01$, $=18{\cdot}1$.

At both stations the older stumps yielded a significantly greater weight of prunings than did the younger stumps. *Tephrosia* significantly reduced the weight of prunings taken in comparison with stumps shaded with collar-pots. Starter fertilizer was significantly beneficial. There were no other significant differences.

The experiment at Mimosa was sited, fortuitously, on an area of soil which was later found to cause severe sulphur deficiency symptoms (STOREY and LEACH, 1933). The beneficial effect of starter fertilizer in overcoming sulphur deficiency was pronounced. No plots receiving starter fertilizer showed symptoms 14 months after the fertilizer was applied. On the other hand, 27 of the 'no starter fertilizer' plots exhibited symptoms to a marked degree, three to a lesser extent and two had no symptoms. At Bvumbwe only a very few randomly scattered plants exhibited symptoms. There were thus decided differences between stations and this is in accord with previous experience. Sulphur deficiency is generally more acute in Mlanje district than in Cholo, and whilst starter fertilizer had no significantly beneficial effects on survival as such, it had a pronounced beneficial effect on the vigour of growth.

At Mimosa a significant interaction existed between the starter fertilizer and shade treatments. As can be seen in *Table 5*, starter fertilizer was proportionately more effective on tea shaded with collar-pots than on tea shaded with *Tephrosia*.

Table 5. Interaction of effects of starter fertilizer and shade

		Shade		
		Pots	Tephrosia	*LSD* = 7·4
Starter	—	23·8	13·2	*at* P = 0·01
fertilizer	+	42·9	20·1	

The extremely severe climatic conditions at Bvumbwe for the 1953–54 replication delayed vegetative growth to such an extent that few plants were ready for pruning in April 1955. Pruning was therefore delayed until the following July. Results for both Mimosa and Bvumbwe are recorded in *Table 6*.

Table 6. 1953–54 pruning weights, expressed as percentages of total yield

Station	*Age*		*Nursery fertilizer*		*Shade*		*Starter fertilizer*	
	18mos.	*30mos.*	—	+	*Pots*	Tephrosia	—	+
Mimosa	52·6	47·4	51·1	48·9	94·7	5·3	50·0	50·0
Bvumbwe	43·9	56·1	53·8	46·2	81·1	18·9	41·5	58·5

LSD Mimosa; at $P=0{\cdot}05$, $=20{\cdot}0$; at $P=0{\cdot}01$, $=27{\cdot}6$.
LSD Bvumbwe; at $P=0{\cdot}05$, $=35{\cdot}1$; at $P=0{\cdot}01$, $=47{\cdot}7$.

At both stations the only significant effects were the reduction in yields due to *Tephrosia*. At neither station was sulphur deficiency of importance.

It will be remembered that during the 1954–55 planting season *Tephrosia vogelii* failed to germinate at Bvumbwe and consequently the shade comparison virtually became one between collar-pots and no shade.

Table 7. 1954–55 pruning weights, expressed as percentages of total yield

Station	*Age*		*Nursery fertilizer*		*Shade*		*Starter fertilizer*	
	18mos.	*30mos.*	—	+	*Pots*	Tephrosia	—	+
Mimosa	40·3	59·7	50·5	49·5	74·7	25·3	49·5	50·5
Bvumbwe	32·6	67·4	52·3	47·7	55·9	44·2	50·0	50·0

LSD Mimosa; at $P=0{\cdot}05$, $=9{\cdot}1$; at $P=0{\cdot}01$, $=12{\cdot}4$.
LSD Bvumbwe; at $P=0{\cdot}05$, $=27{\cdot}9$; at $P=0{\cdot}01$, none.

At Mimosa older stumps significantly outyielded the younger stumps and *Tephrosia* as in previous seasons again caused a significant reduction in yield.

At Bvumbwe the older stumps significantly outyielded the younger. There were no significant differences between the 'shade' treatments, which supports previous results showing *Tephrosia* to be deleterious.

At neither site was sulphur deficiency in evidence.

From the data presented in *Tables 1* to *7* it appears that the best overall results for survival and for vigour of growth were obtained by planting

30-month old stumps, shading these with collar-pots and giving 1 oz. of starter fertilizer per plant.

Table 8 and *Figure 1* record the relationship between percentage deaths and stump diameters at 4 in. above soil level. Each entry is averaged over all treatment combinations, thereby using all the stumps planted. Diameter measurements are given in 1/16-in. steps.

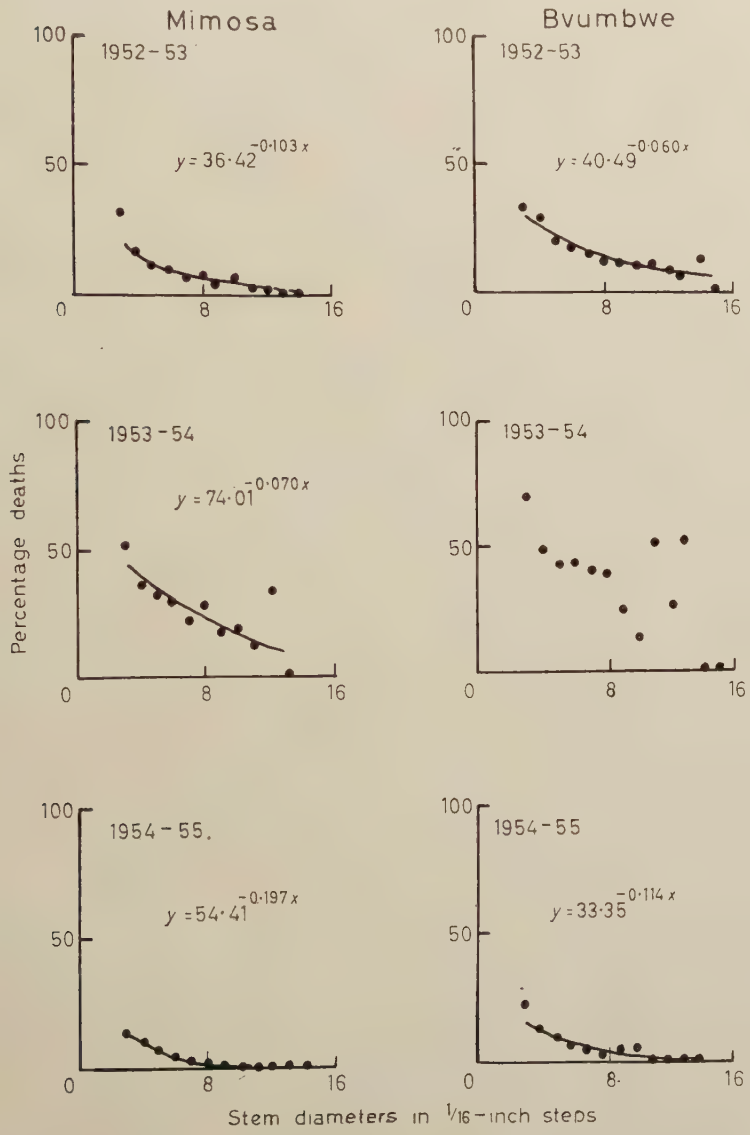

Figure 1. Relationships between stem diameters at 4 in. above soil level and percentages of deaths approximately twelve months after transplanting

Table 8. Stump diameters at 4 in. above soil level and percentage deaths

Station	Season	Stump diameters in 1/16-in. steps						
		3	4	5	6	7	8	9
Mimosa	1952–53	32·1	15·9	10·5	9·5	6·4	7·2	3·7
	1953–54	51·9	37·2	31·5	29·8	21·6	27·2	17·0
	1954–55	13·6	9·5	5·4	3·0	2·2	1·4	0·0
Bvumbwe	1952–53	33·1	28·1	19·8	16·5	14·3	11·5	10·5
	1953–54	68·2	47·0	41·1	42·0	39·0	37·2	23·6
	1954–55	21·6	12·4	9·6	5·6	4·0	1·9	3·9

Station	Season	10	11	12	13	14	15	16
Mimosa	1952–53	6·5	2·4	2·2	0·0	0·0	—	—
	1953–54	18·8	12·5	33·3	0·0	—	—	—
	1954–55	0·0	0·0	0·0	0·0	0·0	—	—
Bvumbwe	1952–53	11·0	10·5	7·5	6·7	12·9	0·0	—
	1953–54	12·5	50·0	25·0	50·0	0·0	0·0	—
	1954–55	4·5	0·0	0·0	0·0	0·0	—	—

At the time of uprooting from the nurseries all live stumps of whatever diameter were taken, there being no selection for size. As a result, unequal numbers of stumps were obtained in each diameter group and typical frequency distributions are superimposed over the main curves in *Figure 2.* Consequently the precision of the relationship is variable between diameter intervals for each station and for each season. Nevertheless the data are adequate to suggest a comparatively systematic relationship between stump diameter and survival and thereby confirm that stump diameter can be used as a practical measure of readiness for transplanting. This point will be further discussed later.

After transplanting, the new plant is leafless and without fine feeder roots. It must therefore be dependent for its new growth upon stored reserves within the remains of its transplanted rooting system already formed in the nursery. No facilities exist at the stations for chemical analysis and it was not possible to arrange to have large numbers of roots analysed elsewhere for their starch content. In lieu of more precise results, an estimate of the stump diameter/stored reserves relationship was obtained by using total fresh root weights—it being assumed that fresh root-weight would be in constant relationship with a quantitative measure of starch reserves.

In 1952, 407 stumps were dug from an 18-month old nursery in groups of about 130 plants, leaving about 150 untouched and growing stumps between each group. Twelve months later these remaining 300 stumps were taken, being by then 30 months old. Two sets of stumps were thereby obtained differing in age by 12 months but otherwise being as near as possible grown under similar seed, soil and cultural conditions. No estimate can be given of the climatic effects of the latter 12 months of growth of the 30-month old stumps.

Immediately after uprooting, the roots were washed clean of surface soil and the stump diameter at 4 in. above soil level was taken with

vernier callipers. The root was cut off at soil level, weighed, cut in two and tested for starch content with iodine solution. The weight and starch estimate were recorded against diameter. Out of 700 stumps so treated

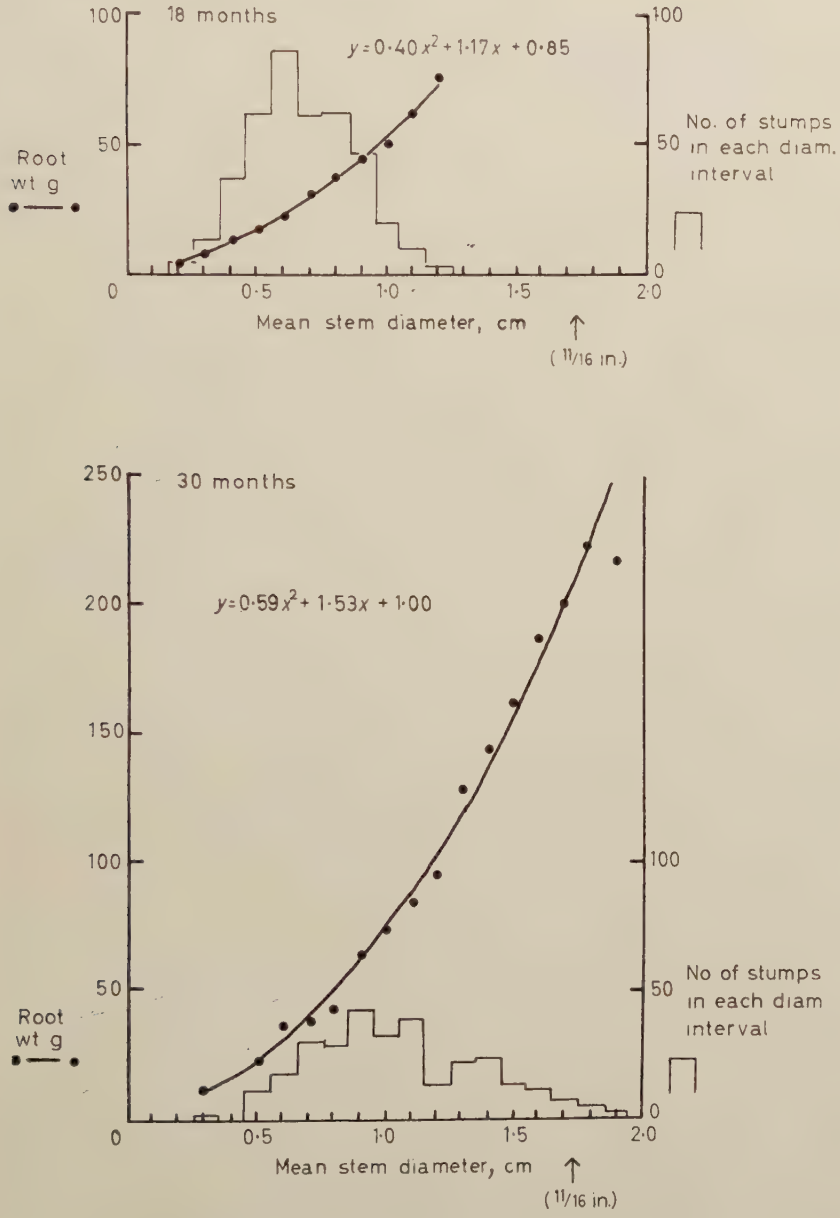

Figure 2. Relationships between stem diameters at 4 in. above soil level and their fresh root weights. Superimposed are frequency histograms of the numbers of stumps obtained in each diameter class. Complete survival was obtained with stumps at or above 11/16-in. diameter (1·74 cm)

only 10 gave no starch reaction, the remainder in every case gave a complete and dense cross section too deep in colour to allow any gradation by eye. The assumption that the reserve foodstuffs are in proportion to root weight is facilitated by this apparent lack of variation in density of starch—disregarding the 10 without any.

The data were then collated and are recorded in *Table 9* and *Figure 2*.

Table 9. Mean stump diameter and associated mean root weight

Mean stump diameter cm	*Mean root fresh weights (g)*		*Mean stump diameter cm*	*Mean root fresh weights (g)*	
	18-month stumps	*30-month stumps*		*18-month stumps*	*30-month stumps*
0·2	4·8	—*	1·1	62·1	84·2
0·3	7·3	11·0	1·2	76·5	95·1
0·4	12·5	—	1·3	—	129·0
0·5	17·3	22·5	1·4	—	143·2
0·6	22·7	35·5	1·5	—	160·8
0·7	30·0	37·1	1·6	—	186·7
0·8	38·7	42·7	1·7	—	199·6
0·9	45·5	63·1	1·8	—	220·3
1·0	50·1	73·2	1·9	—	216·0

*A dash indicates that no plants were available.

Mean root weight within each age group is proportional to stump diameter at four inches above soil level. The 30-month stumps have proportionately heavier roots, diameter for diameter, than the 18-month stumps although this direct comparison is not truly valid because the effects of climate for the latter 12 months cannot be assessed.

These data suggest a reason for using stump diameter as a measure of readiness for transplanting. Diameters are in effect positive measures of root reserves upon which the transplanted stumps will depend for survival and early growth.

The best results in survival and vigour of growth were obtained by transplanting 30-month old stumps, shading these with collar-pots and thereafter applying starter fertilizer. Diameter mortality percentages for this treatment combination are recorded in *Table 10*.

Table 10. Diameter and percentage deaths for the best treatment combination (diameters in 1/16-in. steps)

Station	*Planting season*	*Mean stump diameters in 1/16-in. steps*									
		3	4	5	6	7	8	9	10	11	12 *and over*
Mimosa	52–53	—	5	13	10	9	4	7	4	0	0
	53–54	33	14	7	10	3	2	0	0	0	0
	54–55	30	16	10	2	0	0	0	0	0	0
Mean		31	12	10	7	4	2	2	1	0	0
Bvumbwe	52–53	50	38	21	12	10	6	9	5	0	0
	53–54	—	61	46	23	16	11	15	0	0	0
	54–55	29	12	7	2	0	0	0	0	0	0
Mean		40	37	24	12	9	6	8	2	0	0

Under the conditions of these experiments and this treatment combination, complete survival would have been obtained in all seasons by using stumps of 11/16 in. diameter and over. The stumps used in the diameter/root weight investigations were taken from good nurseries and only three per cent of the 30-month stumps were 11/16 in. and over in diameter (*Figure 2*). Traditional nursery techniques viewed in the light of these data are inefficient. To insist on the use of stumps of not less than 11/16 in. diameter would virtually exclude no less than 90 per cent of seedlings growing in the average nursery.

Variations in mean percentage deaths between seasons can be seen in *Tables 1*, *2* and *3* and it is suspected that these differences are due to inter-seasonal variations in climate—particularly rainfall. Running rainfall totals and long-term averages for the periods between planting and taking survival counts are recorded in *Table 11* and *Figure 3*.

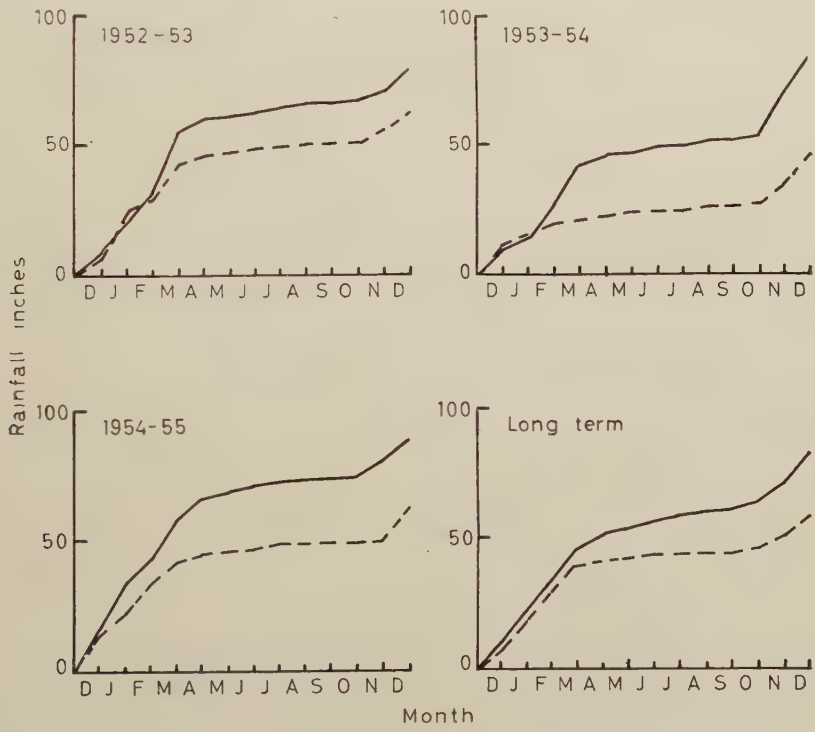

Figure 3. Running rainfall totals for the three seasons in comparison with the long-term means. Mimosa full lines and Bvumbwe broken lines

These patterns demonstrate that at Mimosa the first season was approximately average, the second season below average and the last season above average. At Bvumbwe the first and last seasons approximated to the average whereas the second season was a very severe one.

Three fairly distinct phases can be seen in the rainfall curves; an upward trend during the December to March period following planting, a fairly

Table 11. Running rainfall totals over the survival period and the long-term averages for comparison

	Month	D	J	F	M	A	M	
Mimosa	1952–53	8·76	20·09	31·23	55·12	59·98	60·63	
	1953–54	8·07	13·80	27·50	42·56	45·61	46·32	
	1954–55	15·18	33·13	43·89	57·27	66·26	69·61	
	Long term	10·99	22·78	34·54	46·76	51·18	54·26	
Bvumbwe	1952–53	6·29	20·45	29·75	42·01	46·36	47·05	
	1953–54	8·63	14·00	18·28	21·67	22·33	23·41	
	1954–55	12·93	21·99	33·72	40·99	44·32	45·08	
	Long term	7·56	18·50	29·70	39·13	41·37	42·22	
	Month	J	J	A	S	O	N	D
Mimosa	1952–53	62·87	65·54	65·79	66·90	67·69	71·48	79·55
	1953–54	49·02	49·05	51·17	51·35	52·27	68·48	83·66
	1954–55	71·32	72·04	73·19	73·60	74·72	81·50	89·99
	Long term	56·40	58·13	59·98	60·58	64·03	71·82	82·81
Bvumbwe	1952–53	48·00	49·76	50·01	50·25	51·87	56·09	64·72
	1953–54	24·72	24·81	25·34	25·55	26·87	33·25	46·18
	1954–55	45·81	46·04	46·22	46·32	46·52	48·28	62·55
	Long term	43·19	43·82	44·16	44·65	45·75	50·63	58·19

stationary trend throughout the dry season April to October, followed by a rise again with the new rains in November and December, after which few surviving plants are expected to die.

Correlation coefficients between mean percentage deaths and rainfall totals are given in *Table 12.*

Table 12. Correlation coefficients between percentage deaths and rainfall totals

Station	*Rainfall period*		
	Dec. to Mar.	*Dec. to Oct.*	*Dec. to Dec.*
Mimosa	—0·9981	—0·9949	—0·3244
Bvumbwe	—0·9940	—0·9638	—0·9850

(Value for significance: at $P=0·05$, $=0·8783$; at $P=0·01$, $=0·9587$; at $P=0·001$, $=0·9912$.)

The total seasonal rainfall at Mimosa is not closely correlated with the percentage of deaths and this is mainly accounted for by the abnormally high amounts of rain which fell in November and December 1954 after an otherwise below-average season. Otherwise the high negative correlation coefficients suggest a positive dependence for survival upon rainfall quantities following planting (other treatments being equal) and that the inter-seasonal differences in mean deaths obtained in these experiments are possibly due in a large part to inter-seasonal differences in rainfall.

DISCUSSION

These series of experiments have not produced any fundamentally new concepts but they have succeeded in rationalizing previous rule-of-thumb methods and suggesting new research problems.

The high correlation coefficients listed in *Table 12* suggest that survival

between seasons is directly and closely related to the quantity of rainfall following transplanting. Although extrapolation is normally an unreliable practice there appears to be little danger in extending that conclusion and stating that within any season the best results will be obtained by planting as early as possible in the season so that the maximum possible rainfall of that season may be enjoyed. New root initials are not developed until two weeks after transplanting (ANON., 1952–53) and provided stumps are planted in moist soil to assist callousing, there appears to be no need for excessive rainfall during the first two or three weeks following transplanting.

Suitable stumps have roots between 18 and 24 in. long. Soil moisture measurements started in 1956 show that in November 1956 this depth of soil was filled to Field Capacity from Permanent Wilting Percentage with a total rainfall of about 5·75 in. Inter-seasonal differences in rainfall are too great to allow this specific total to be anything more than an indication, but the confidence in rainfall in December is such that there is little risk of a drought following early December planting and root initials will then be formed at the end of the month or in early January when rainfall expectation is good (LAYCOCK, 1954).

The diameter of a seedling at 4 in. above soil level appears to be a convenient and adequate means of assessing its suitability for transplanting as a stump.

Stumps of 11/16 in. diameter and over would have given complete survival in all seasons under the best treatment combination used in these experiments but in practice such a diameter would exclude, in 30-month old average nurseries, not less than 90 per cent of all the seedlings and in 18-month old nurseries virtually all stumps. In these circumstances it would not be practicable to insist on this criterion and some lowering of the standard is necessary until such time as more efficient nursery techniques are discovered. Any lesser standard must be arbitrary but it is considered that an aim of 90 per cent survivors is not unreasonable and this would have been obtained at both stations by using stumps of 7/16 in. diameter and over. (Five- or six-sixteenths would have been adequate at Mimosa but in advisory work it causes less confusion if one safe standard can be set for the whole industry.) A diameter of 7/16 in. is at present therefore the recommended minimum and average nurseries will produce between 40 and 60 per cent of 30-month old seedlings at or above this recommended diameter. This yield of plantable stumps is considered to be poor and it follows that the next step is the improvement of nursery techniques, a process which will be greatly facilitated by having a declared target at which to aim. Previously the results of nursery treatments were assessed by their effects on plot mean stump diameter, an unsatisfactory method.

No satisfactory information was available on the use of nursery fertilizers at the start of these experiments and the rate and mixture used was chosen in the light of general estate practice at that time. Consequently the general lack of response to nursery fertilizers either in survival or with pruning weights cannot be interpreted as meaning that nursery fertilizers are of little or no benefit. Research is needed before any precise picture can be given.

Starter fertilizer has its most profound beneficial effect when sulphur

deficiency occurred on the experimental site and this was due to the sulphur contents of the sulphate of ammonia and superphosphate in the mixture. In the absence of inherent sulphur deficiency no significant effects were obtained from the fertilizer which suggests that the three major plant nutrients in the soil were adequate at both sites. This is in accord with data from more critical experiments on newly planted and young tea, which suggest that when sulphur is adequate no responses can be expected after planting from nitrogen, phosphate or potash, either singly or in combination (ANON., 1955–56b). Sulphur deficiency appears in sporadic areas, not easily predicted before planting; consequently it would appear to be prudent to apply sulphur-bearing fertilizers as a precautionary measure. In these experiments, starter fertilizer was placed at the time of planting or immediately afterwards. Subsequent observations on the newly developing rooting system lead to the belief that more efficient use of fertilizer would be expected if application is delayed until one month after planting (ANON., 1952–53).

The most consistent response to treatments was the deleterious effect of *Tephrosia* on both survival and vigour of growth. Current observations with the low-growing *Stylosanthes gracilis* recently suggested as a suitable cover crop under Far Eastern conditions (MACALPINE, 1956) indicate that this plant too is having a distinctly adverse effect in Nyasaland. No precise reasons can be given for these effects but it is possible that competition for inadequate soil moisture reserves is largely responsible, particularly over the extended dry season.

SUMMARY

Tea planting and replanting programmes are proceeding apace in Nyasaland and, in view of the unsatisfactory nature of the resulting stands that have frequently occurred, a series of observations was undertaken leading to the laying down of a sequence of formal establishment experiments carried out over three planting seasons.

Under the experimental conditions best average results were obtained by transplanting 30-month old stumps, shading their collars with pots, and by giving to each stump a starter dressing of one ounce of a 6:10:8 fertilizer mixture whose ingredients were sulphate of ammonia, superphosphate and muriate of potash.

Tephrosia vogelii grown as a cover crop between the tea rows was detrimental to both survival and vigour of growth.

Seedling diameter at 4 in. above soil level is a good and easy measurement of suitability for transplanting and stumps with diameters of 11/16 in. or over gave complete survival in all seasons. Unfortunately present nursery techniques are inefficient and 30-month old nurseries yield not more than 10 per cent of stumps at this standard. Further investigation into nursery methods is necessary.

Rainfall following planting appears to play an important and positive part in successful establishment, leading to the conclusion that planting with the early rains is essential if best results are to be obtained.

(*Received March 1957*)

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Book Reviews

THE UNDERGROUND ORGANS OF HERBAGE GRASSES

A. Troughton. Commonwealth Agricultural Bureaux: Farnham Royal, Bucks., 1957. ix+163 *pp.* (illus.) 25*s*

This book is bulletin No. 44 of the Commonwealth Bureau of Pastures and Field Crops.

The object of the bulletin is to review the literature concerned with the underground organs of herbage grasses, i.e. the roots, rhizomes, corms etc. of grasses valued for their foliage. However, the author has not restricted himself to this topic alone, including discussions on the behaviour of above-ground organs in relation to those underground wherever this was thought to be relevant. This approach to the subject has increased the value of the book and a good deal more information of agricultural interest is presented than is at first apparent from the title.

The first part of the book deals comprehensively with the morphology, anatomy, life-history and chemical composition of the underground organs. This section, apart from the chapter on chemical composition, is largely descriptive, serving as a very useful but often neglected background to the subsequent chapters.

The second part of the book is of interest to a wider field of readers. Edaphic, physical and physiological factors affecting the growth of the underground organs of grasses are adequately reviewed and the effects of these factors on top growth are also discussed where necessary.

The third and fourth parts of the book, ' the effect of the plant upon the soil ' and ' methods employed in the study of underground organs ' are adequate within the terms of reference of the book title.

In short, this book will be of particular interest to those who want a general introduction to the part played by the underground organs of grasses in the production of herbage and the improvement of soil fertility. —R.N.

FOOD PLANTS OF THE SOUTH SEA ISLANDS

E. Massal and J. Barrau. South Pacific Commission: Noumea, New Caledonia, 1956. 52 *pp.* (illus.) 6*s*

This technical paper makes a most excellent addition to the already well known series produced by the South Pacific Commission on various subjects. It deals with the description of the food plants of the South Sea Islands in two sections, the staple food plants of the area and the supplementary food plants. It is well illustrated with photographs and freehand drawings.

Whilst much of the information contained in the paper, such as the colloquial names of plants and methods of preparation of the various foods are peculiar to the Pacific area, the authors have collated a great deal of general information, which is of value in other parts of the tropics. Of

particular interest are the descriptions of the root crops, many of which are so important in that area.

It is a paper that can be recommended to all who are interested in tropical agriculture.—J.S.C.

MINERALS IN PASTURE : DEFICIENCIES AND EXCESSES IN RELATION TO ANIMAL HEALTH

F. C. Russell and D. L. Duncan. 2nd edn. Commonwealth Agricultural Bureaux, Farnham Royal, Bucks. (Commonwealth Bureau of Animal Nutrition Technical Communication No. 15.) 1956. 25*s*

This communication was first published in 1944 and has now been revised and augmented in the light of developments in the field of mineral metabolism since that time. In order to achieve this revision advice and information have been sought from research workers in many countries thus making this second edition a very complete record of the present state of knowledge.

The subject matter is divided into chapters on all the minerals commonly found deficient or in excess throughout the world. In each chapter full descriptions of clinical symptoms, pasture and soil analyses and experiments carried out are given; also summaries of present knowledge. The two longest chapters occupy some two thirds of the total space and deal with the many deficiency diseases of copper and cobalt. An exhaustive critical survey of experimental work on the deficiency of these two minerals in many countries is given, bringing together much information from widely separated sources.

Throughout this publication the individual treatment of each mineral and the very many disease conditions described make it a very useful book of reference on all aspects of mineral deficiency in pastures. A very complete bibliography is given on every topic and the presentation is so thorough as to make criticism of detail invidious. One irritating point, however, is the lack of an index which would definitely add to the usefulness of the book.—T.R.H.

A BIOLOGY FOR THE WEST INDIES AND BRITISH GUIANA

V. Graham. Macmillan and Co. Ltd: London, 1956. vii+308 *pp.* (over 300 illus.) 15*s*

Miss V. Graham's recent addition to the few existing textbooks on biology for regions other than temperate is a disappointing attempt to fill a gap that teachers and students in the tropics must have felt for many years. Valuable though this book may be in presenting, within two covers, biological details of tropical examples, it is regretted that for a number of reasons this book cannot be recommended as an indispensable aid to the biology classroom.

The book is described as covering the syllabuses for School Certificate and Ordinary Level Examinations for the G.C.E., as well as containing

further material for the first year of Sixth Form work. Except for approximately 30 pages at the beginning and the last chapter on ecology, the work falls neatly into two clear-cut categories—the plant and the animal kingdoms. It is this strictly segmented treatment of biology that the reviewers consider to be a prominent failing of the author and to merit criticism, particularly in view of the considerable degree of emphasis now given in the examination syllabuses to close integration and comparison in biology teaching. When dealing with reproduction for instance, Miss GRAHAM discusses her examples intermittently throughout the book in distinct and separate sections whereas it is thought preferable that reproduction should be treated under one heading, first in terms of binary fission, budding and spore formation in relation to simple plants and animals, developing, subsequently, into details of higher organisms with final discussion on subjects such as division of labour, sexuality, variation, protection and dispersal. Surely the student would then be better fitted to think from a biological standpoint and to regard biology as biology, and not as classes in botany and zoology.

Another major criticism foremost in the reviewers' minds concerns the teleological approach which pervades the whole book and which is particularly prevalent in botanical descriptions. The impression given is that plants and animals develop certain features *in order to* exploit or survive in an ecological niche rather than that they *are able to exist* in a particular habitat because they possess certain adaptations to the environment. This is seen as an uncritical and loose manner of thought which, in the reviewers' experience, is extremely difficult to eradicate once implanted in the minds of the young. Thus it seems unforgivable that a student using this volume might enter the examination room likely to perpetrate ideas such as these:

> '. . . the single layer of cells on the outside of the stem is thickened or cutinized to prevent it drying up . . . plants growing in dry situations develop devices to reduce this [water] loss . . . the plant ensures its survival by making more of its kind . . . the fruit is used by the plant for spreading its species . . . dry fruits with more than one seed must separate these seeds so that they do not become overcrowded when they begin to grow.'

It is also felt that the student reading the book will be in danger of accepting dogmatic statements and likely to experience difficulty in understanding some passages; even being confused in places where a distinction may be inferred when the author writes of ' trees and plants with flowers ' page 62 and ' corn and grasses ' page 71. Of greater importance is the occurrence of too frequent errors. Students who have been taught that spiracles in the cockroach are found in the first thoracic segment and in nine of the abdominal segments; that the proboscis of a butterfly or moth is formed from the inner ' blades ' (laciniae) of the maxillae; that osmosis is the process by which a weak solution is drawn into a stronger solution through a semi-permeable membrane; that root hairs absorb their water and mineral salts by the process called osmosis; etc., etc., are certainly going to possess a poor foundation in biology. Furthermore the statement made regarding reproduction of aphides is suspect for tropical conditions and surely the ' air sacs in bones to make them lighter ' myth has died a

natural death. Is photosynthesis the reverse of respiration ? Nevertheless the useful suggestions for practical work given at the end of the chapters will be found valuable in presenting to the student a wide practical background.

The reproduction of photographs is not good and it is regretted that most line illustrations have been presented without due attention to the fundamentals of good biological drawing. For a large number of the illustrations unnecessary shading and careless lines have obscured detail and reduced accuracy. It is noted that the author's drawings tend to compare unfavourably with those from other sources and in this respect it is felt that the publishers should have been of greater guidance to the author.

However, it gives the reviewers great pleasure to find in the last chapter a section to which Miss GRAHAM has happily and well advisedly devoted much of her attention. Ecology is obviously her strong point and if she can stimulate the interest of students through the medium of natural history then an extremely valuable contribution will have been made to the teaching of biology in the tropics. Perhaps the frequency of errors may, in part, be attributed to lack of access to literature but here the reviewers feel strongly that the editor must share some of the blame for allowing them to stand.—P.T.R. and M.H.B.

MODERN COFFEE PRODUCTION

A. E. HAARER. Leonard Hill (Books) Ltd: London, 1956. xiv+467 *pp.* (illus.) 56*s*

Mr HAARER has obviously taken immense pains in producing this work on coffee which is replete with facts and references to the literature. The resulting book will, however, appeal to coffee planters more than to agricultural scientists. The author's *forte* is practical experience of coffee management in East Africa, and on this he has many wise and sensible things to say, which should provide useful guidance for the young planter. Where he essays a more scientific level, neither his language nor his meaning are always so clear. Thus a discussion on whether a coffee tree always makes a tap-root ends in the conclusion that ' If it wants to it will '. A useful conspectus of coffee-growing in different regions of the world forms part of the book. The text is marred by some consistent spelling errors such as ' Albizia ' for ' Albizzia ' and ' kabatic ' for ' katabatic '.—G.B.M.

LOSSES CAUSED BY PLANT DISEASES IN THE COLONIES

G. WATTS PADWICK. Commonwealth Mycological Institute: Kew, 1956. 60 *pp.*, 10 *pl.*, 6 *graphs*, 1 *map*. 10*s*

In this comprehensive paper, the first of a series of Phytopathological Papers published by the Commonwealth Mycological Institute, the author discusses the losses caused by plant diseases in the crops grown in the British Colonies mainly from the point of view of the difficulties in their estimation.

After a short introduction, the more important diseases are discussed under the three main headings of permanent and semi-permanent crops,

vegetatively propagated crops, and crops grown from seed. In the third part of the paper the methods used by the Colonial Plant Disease Survey are explained, and losses given for the main crops using the percentage loss in yield to permit a direct comparison between both the different crops and between the same crops in different colonies.

Following the discussion and summary there is a full bibliography, and the paper ends with an appendix which gives the estimated crop losses in great detail. The losses are divided into three categories, over 10 per cent loss, important losses under 10 per cent, and small or very small losses. Beside each crop are shown the colonies where it is grown with the area it occupies, the different diseases which cause damage in each place, the losses they cause, and the main references from which the estimates were made. The overall loss averaged from all the crops considered is reckoned at 11·8 per cent.—R.F.B.

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Flora of Trinidad and Tobago: This Flora, which has been issued irregularly in parts since 1928, is a compilation of the work of many authors. The early parts, mainly by R. O. WILLIAMS, were edited by the Department of Agriculture of Trinidad and Tobago, but since the end of the 1939–45 war editing has been taken over by the Botany Department of the Imperial College. The Flora may be obtained either from the Department of Agriculture or from the Imperial College. The following parts have been published :

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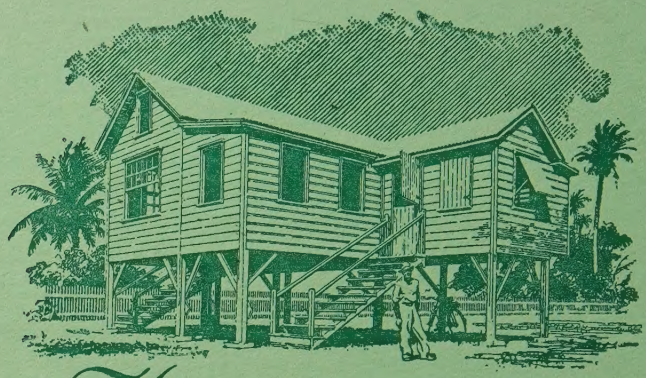

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